



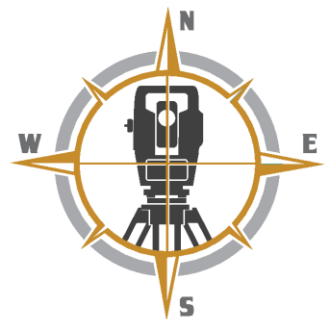
جامعة الأمير مقرن بن عبد العزيز
University of Prince Mugrin

AE 475 - Surveying

Lecture 4



Leveling



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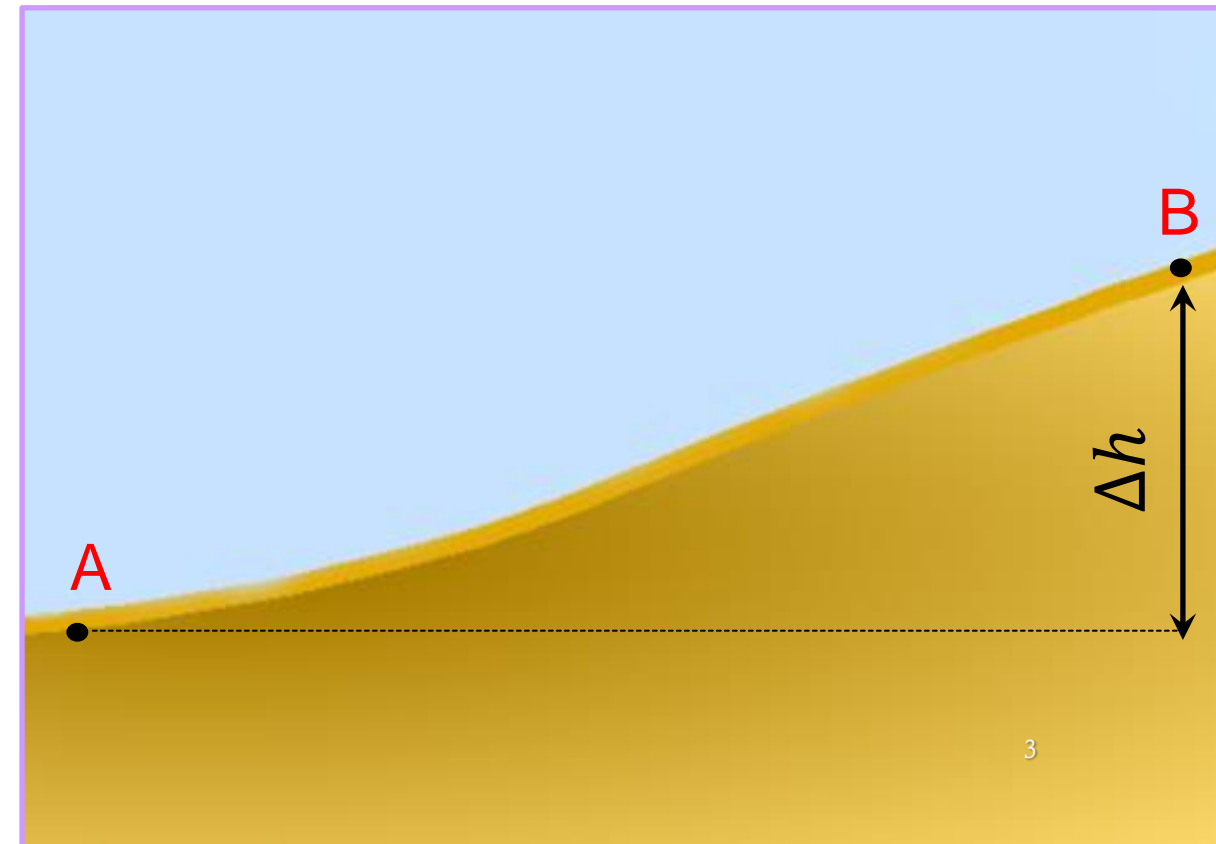


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Leveling is the name given to the process of measuring the **difference in elevation** (vertical position) between two or more points **below**, **on**, or **above** the ground.

Leveling has many applications and it is a vital operation in producing necessary data for **mapping**, **engineering design**, and **construction**



Leveling results are used to:

- (1) design highways, railroads, canals, sewers, water supply systems.
- (2) lay out construction projects according to planned elevations;
- (3) calculate volumes of earthwork and other materials;
- (4) investigate drainage characteristics of an area;
- (5) develop maps showing general ground configurations.

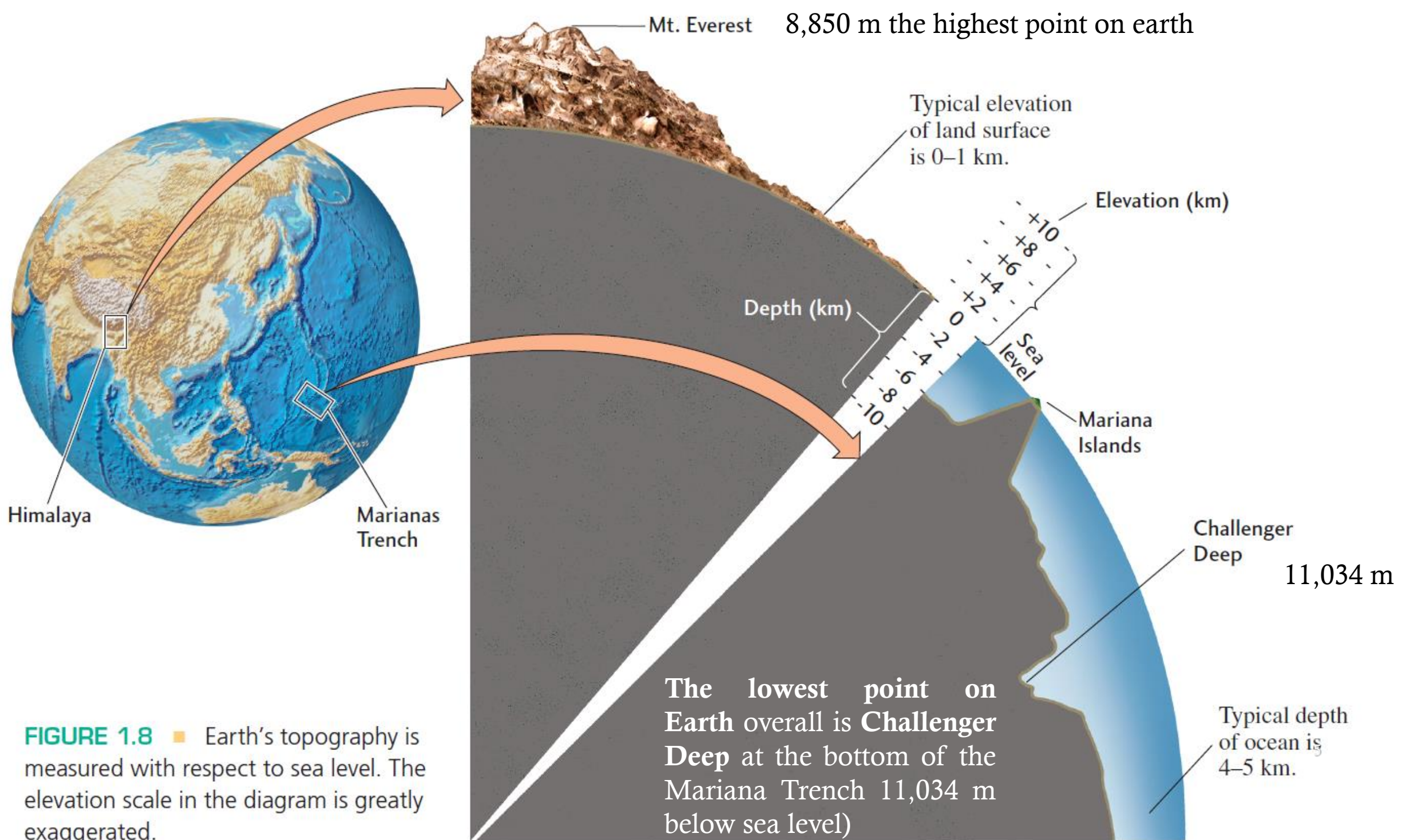


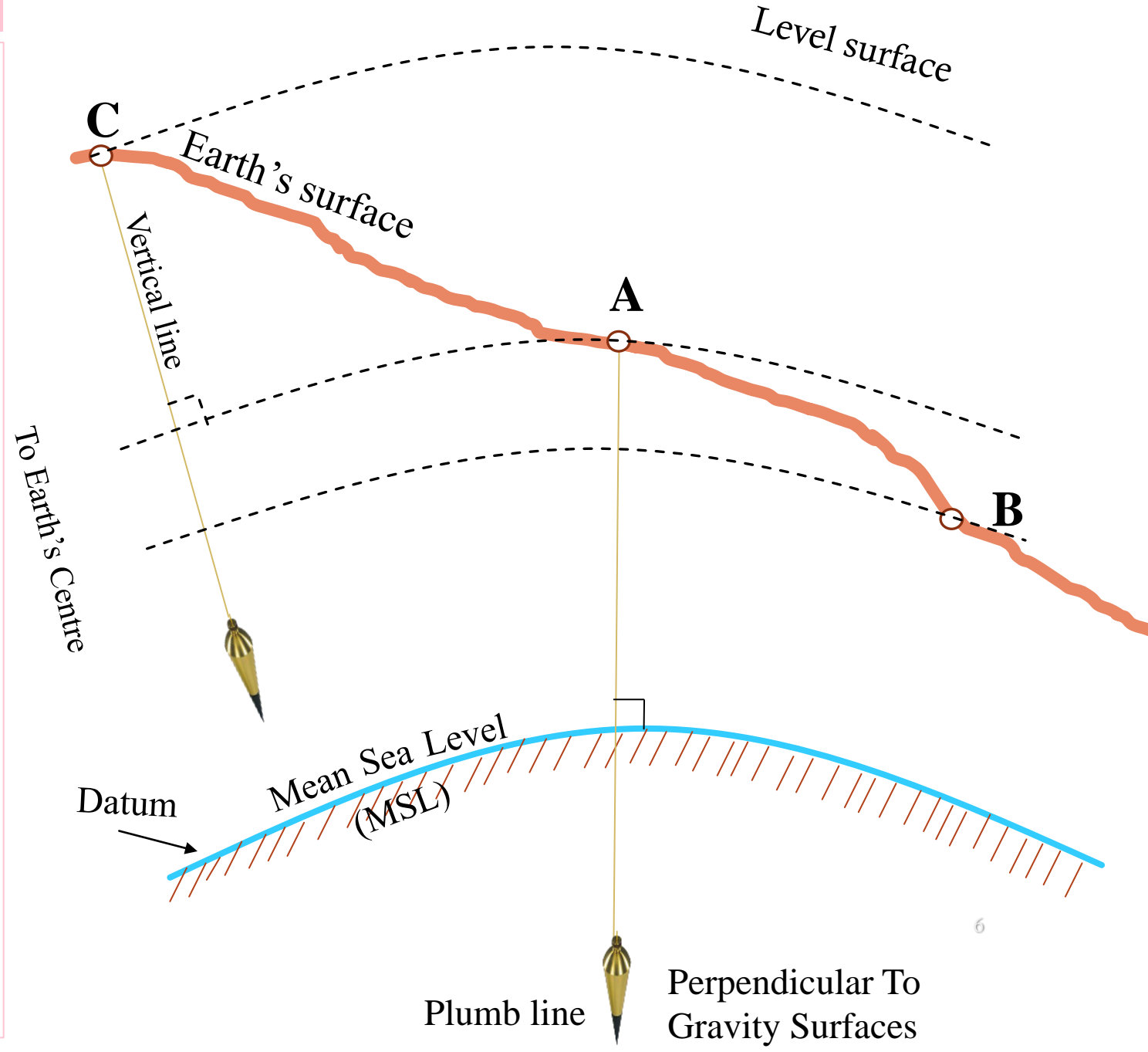
FIGURE 1.8 ■ Earth's topography is measured with respect to sea level. The elevation scale in the diagram is greatly exaggerated.

Definitions

A **datum** is any **reference** surface to which the elevations of points are referred. The most commonly used datum is that of **mean sea level (MSL)**.

Vertical line is a line from the surface of the earth to the earth's center. It is also referred to as a *plumb line* or a *line of gravity*.

A **level surface** is a **curved** surface **parallel** to the mean surface of the earth. A level surface is best visualized as being the surface of a large body of water at rest.

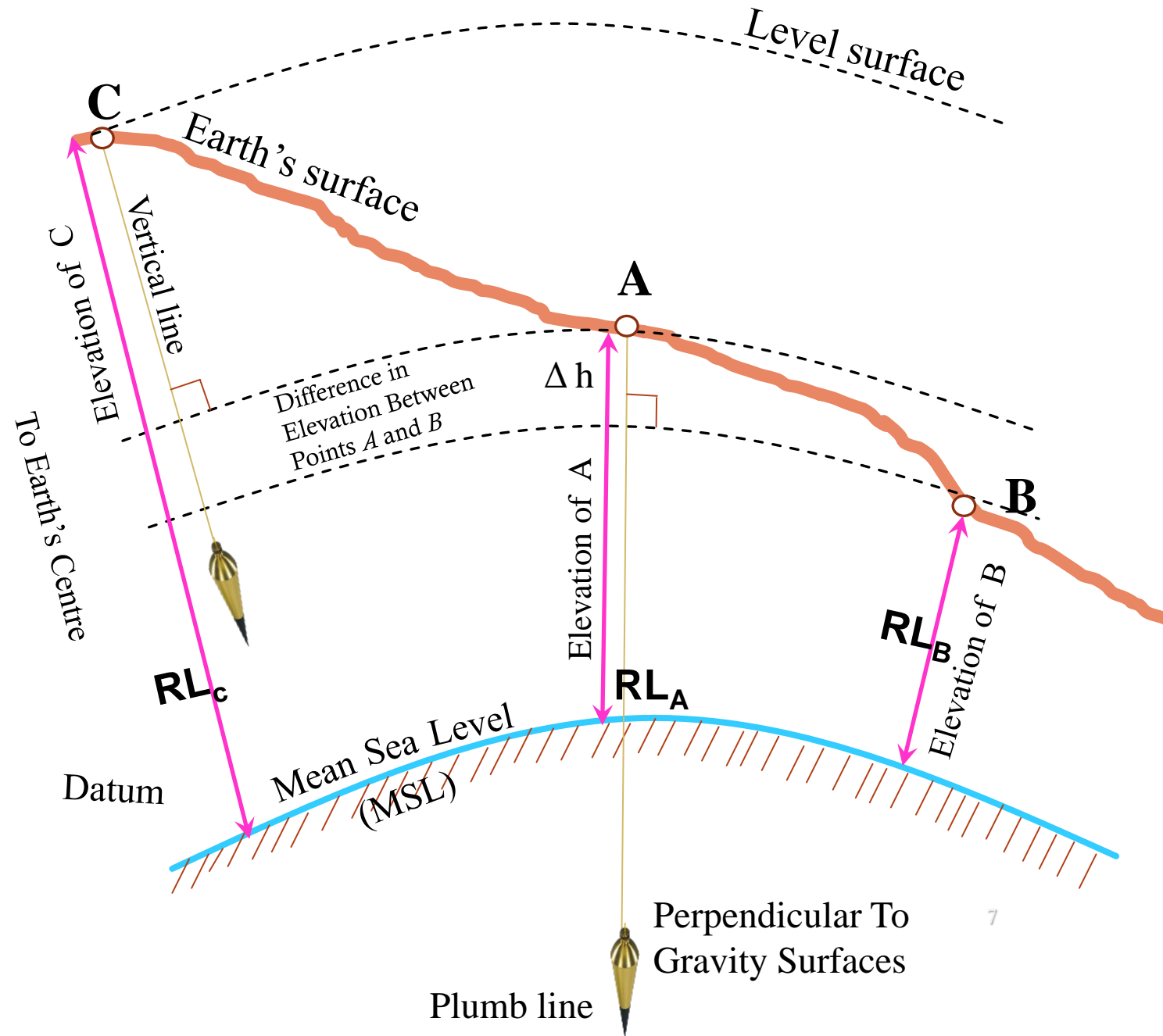


Definitions

A **Reduced Level (RL)** of a point is its height above or below a reference **datum**.

A **bench mark (BM)** is a **permanent** point of **known** elevation. It is located by arbitrary assignment of a fixed elevation or by extension of vertical control.

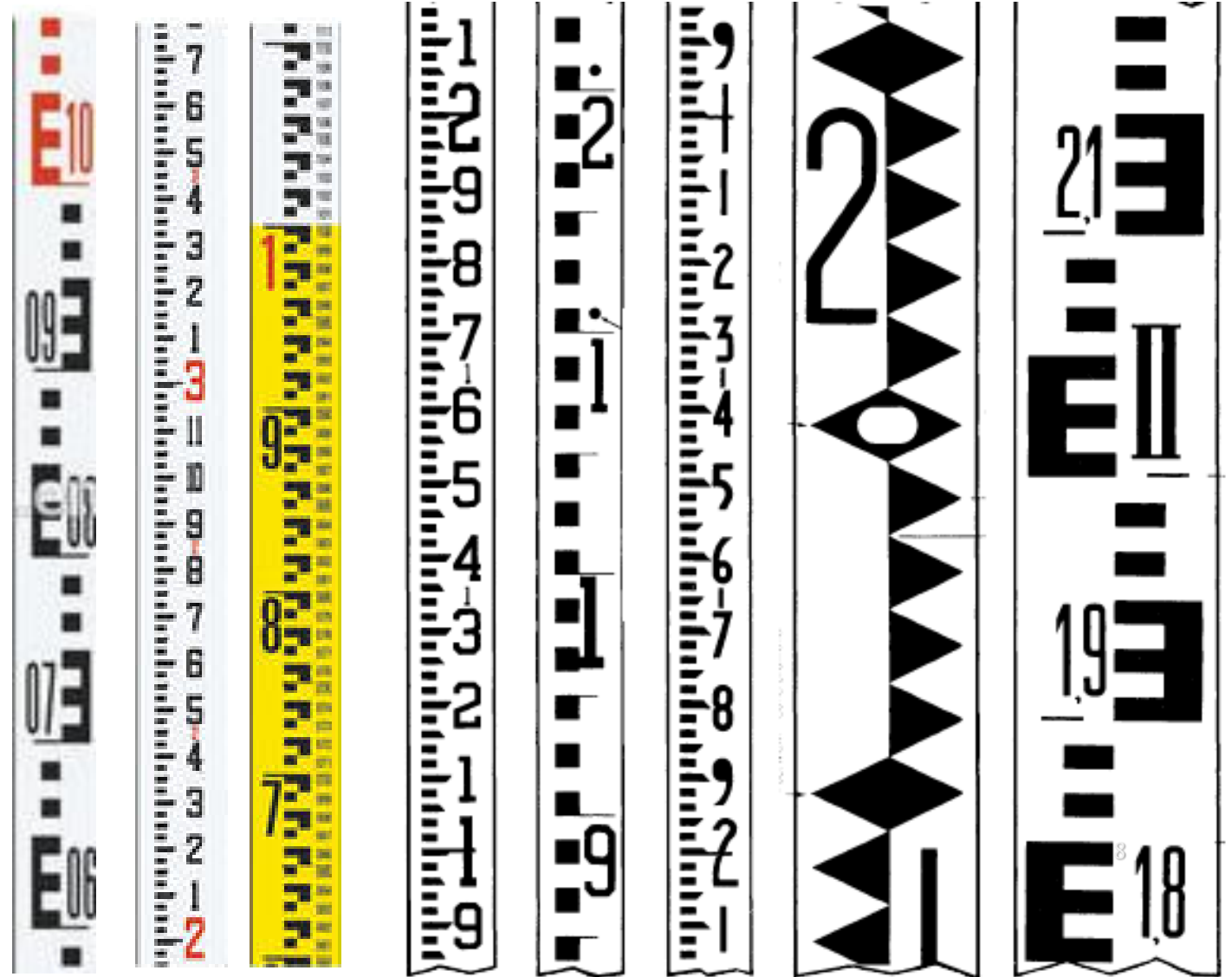
Temporary or transferred bench marks (TBMs) are marks set up on stable points near construction sites to which all levelling operations on that particular site will be referred.



Equipment

The equipment used in the levelling process comprises **levels** and **graduated staffs**.

Level instrument



Automatic level

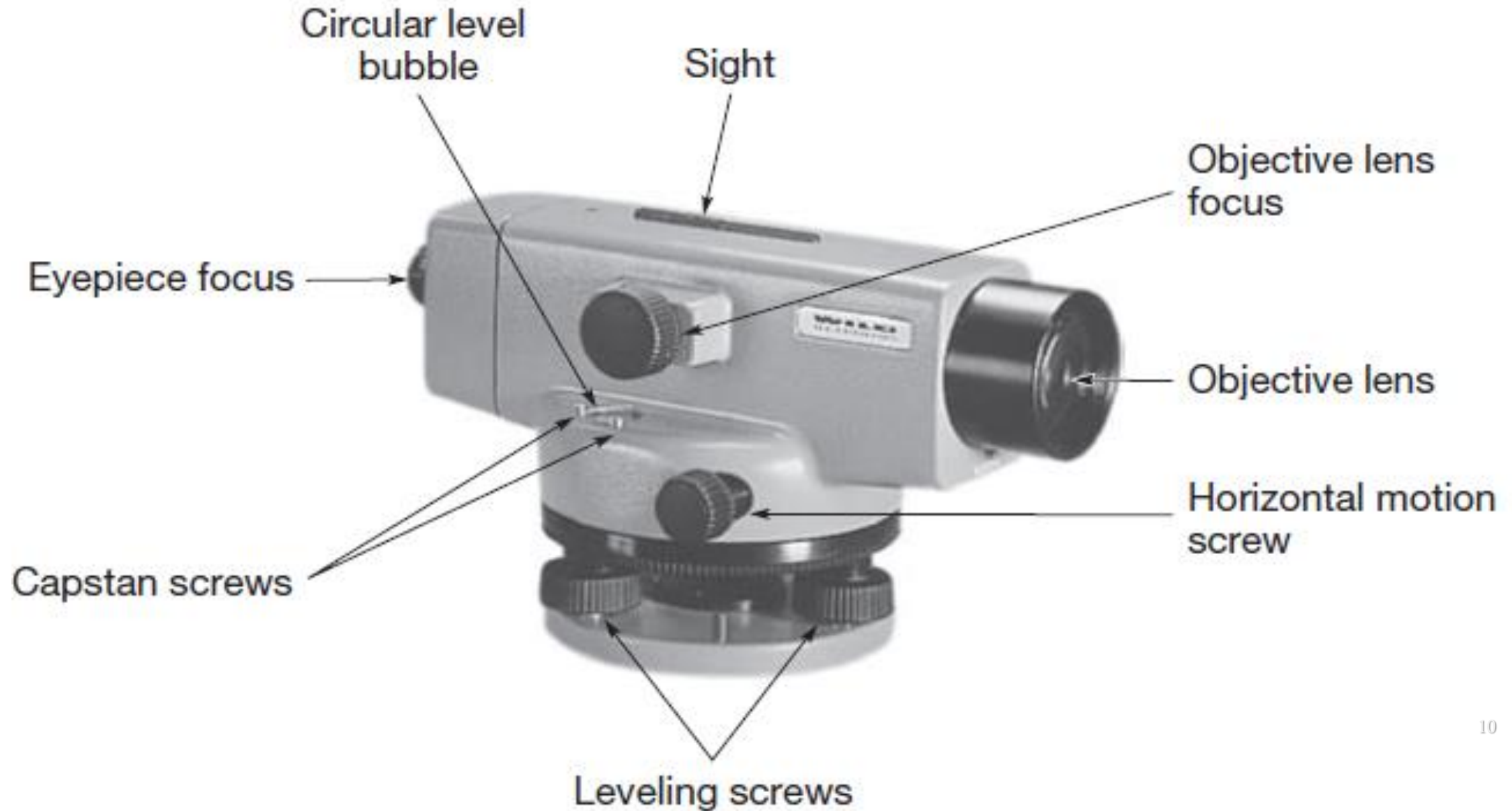


A **Level** consist of high-powered telescope. The level is attached to a spirit or bubble level that keeps the line of sight of the telescope horizontal



Instrument is leveled into a **horizontal** position by means of **spirit bubble**. Spirit bubble is in a transparent container filled with a low viscosity liquid, e.g. alcohol or ether.

Automatic level



- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble (bull eye)
- Marker

Automated Levels

Easy to use (not power!)

Needs experience

Robust even in hostile environment



Digital Levels

Push-button technique

No reading errors, special staff

Readings are stored and analyzed digitally



-Level Instrument

-**Tripod**

-Staff/Pole

-Change plate

-Pole staff bubble (bull eye)

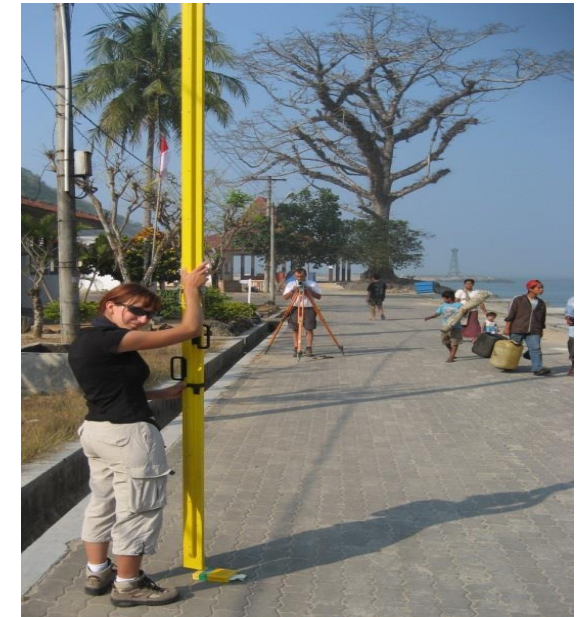
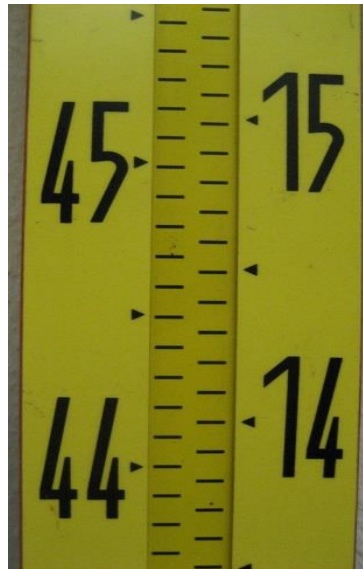
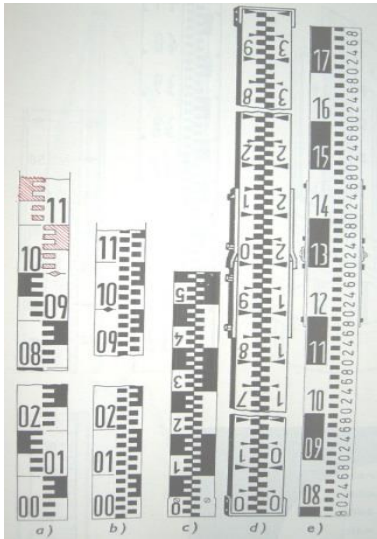
-Marker

- Wooden design or aluminum
- From “easy to sit” to “ops, this is high”



- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble (bull eye)
- Marker

- Wood, aluminum
- INVAR type for high precision leveling



- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble (bull eye)
- Marker

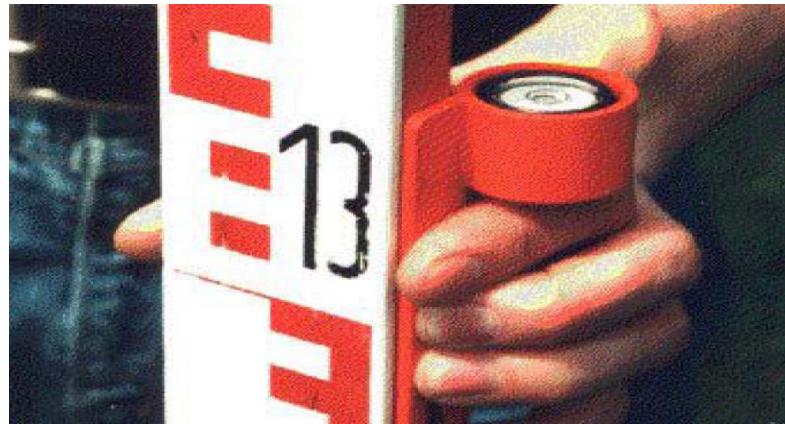
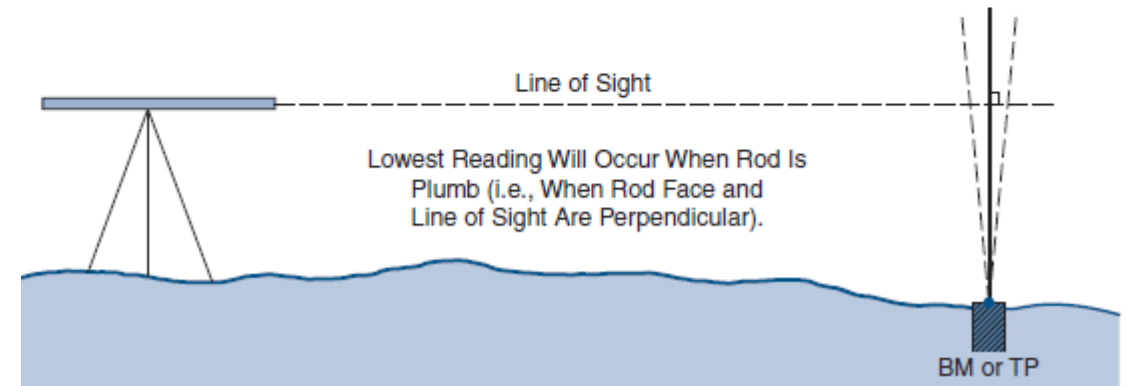
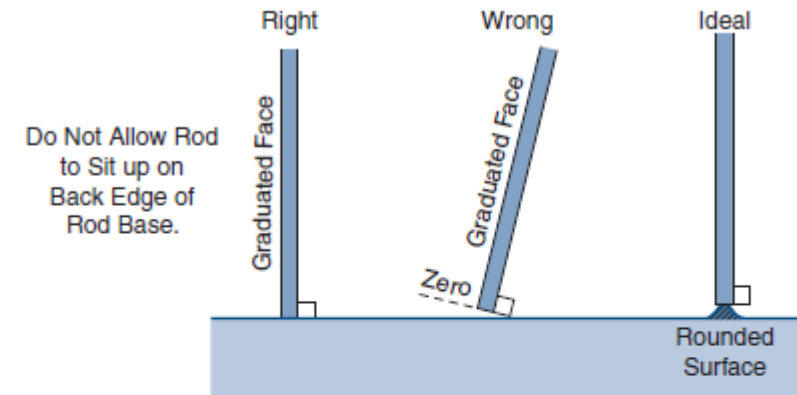


A Staff change plate is a small flat metal plate with a raised point in center that is used to support the ground. The plate is firmly embedded into the ground to stop the staff from subsiding



- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble (bull eye)
- Marker

Keep the pole upright
Any tilt will disturb your readings



- Level Instrument
- Tripod
- Staff/Pole
- Change plate
- Pole staff bubble (bull eye)
- Marker

Gives you a fixed point

Should be of good quality

Should be long-term

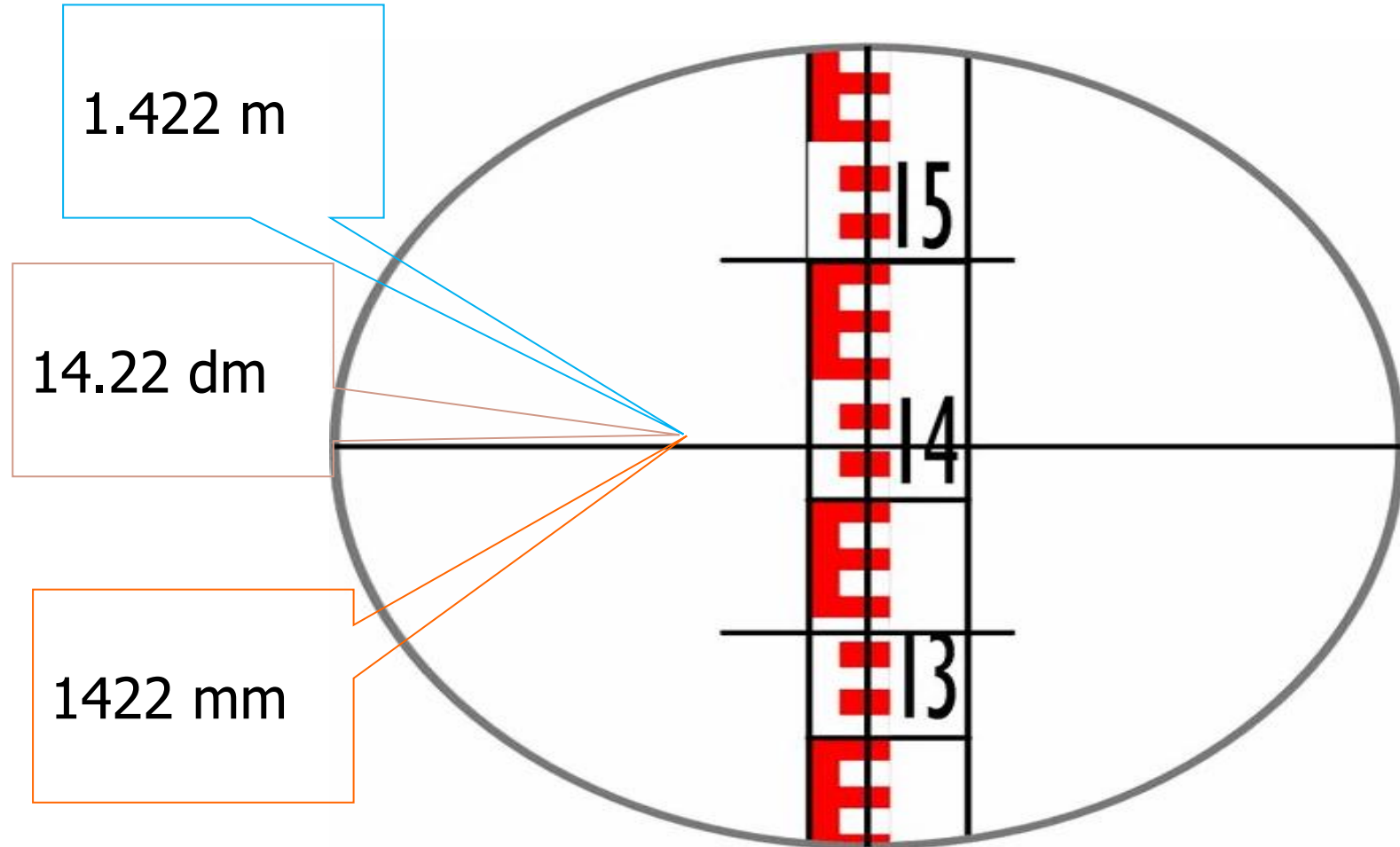
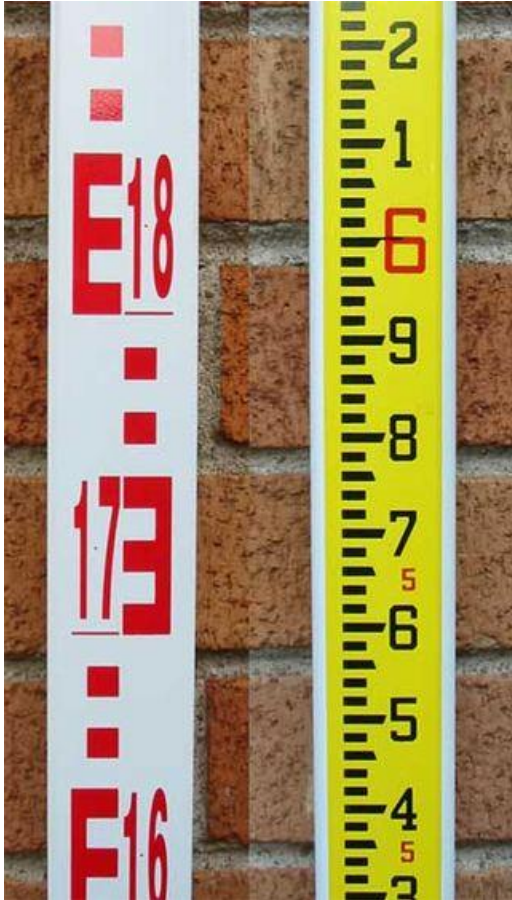
Preferable in bedrock, settled buildings, or bridges

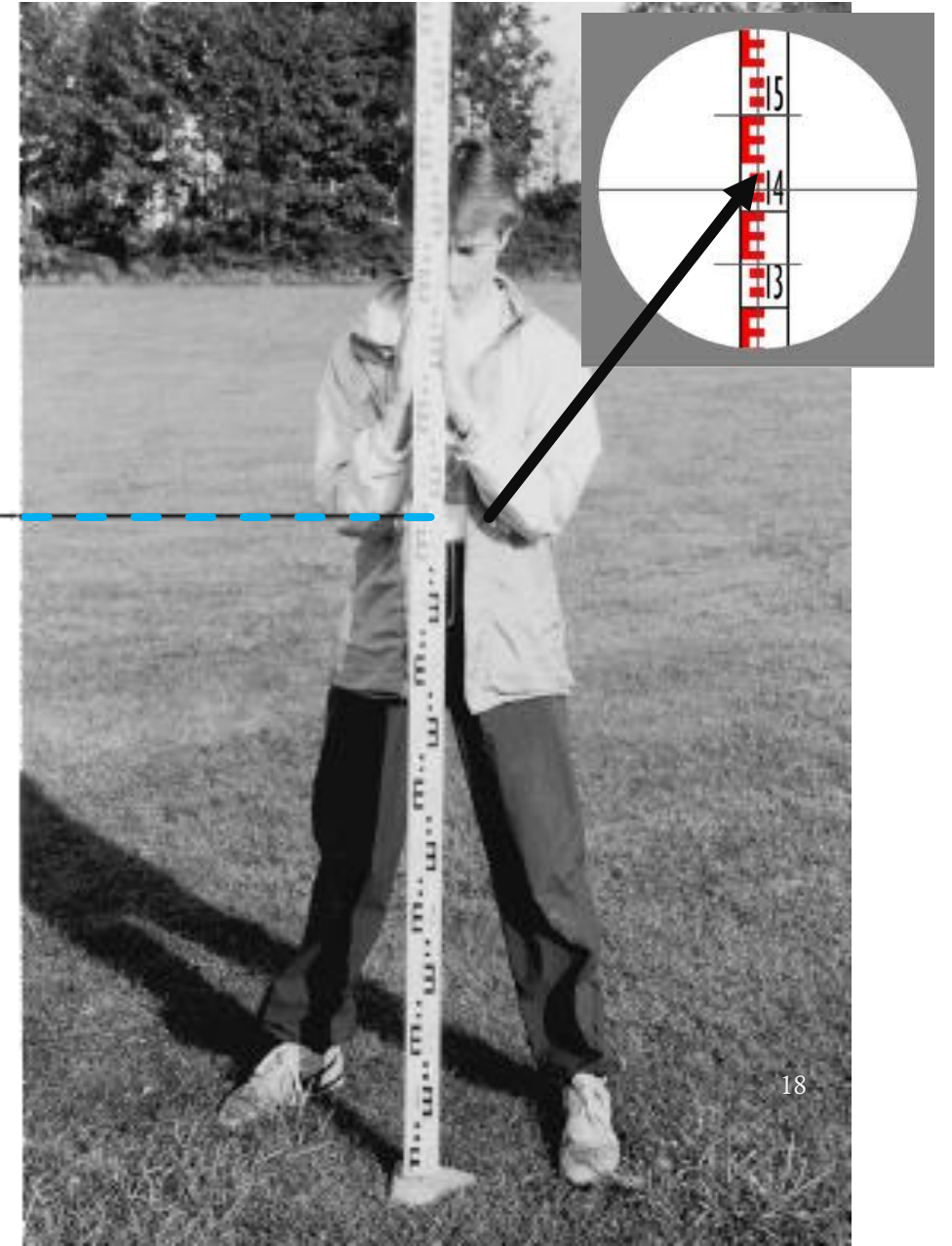
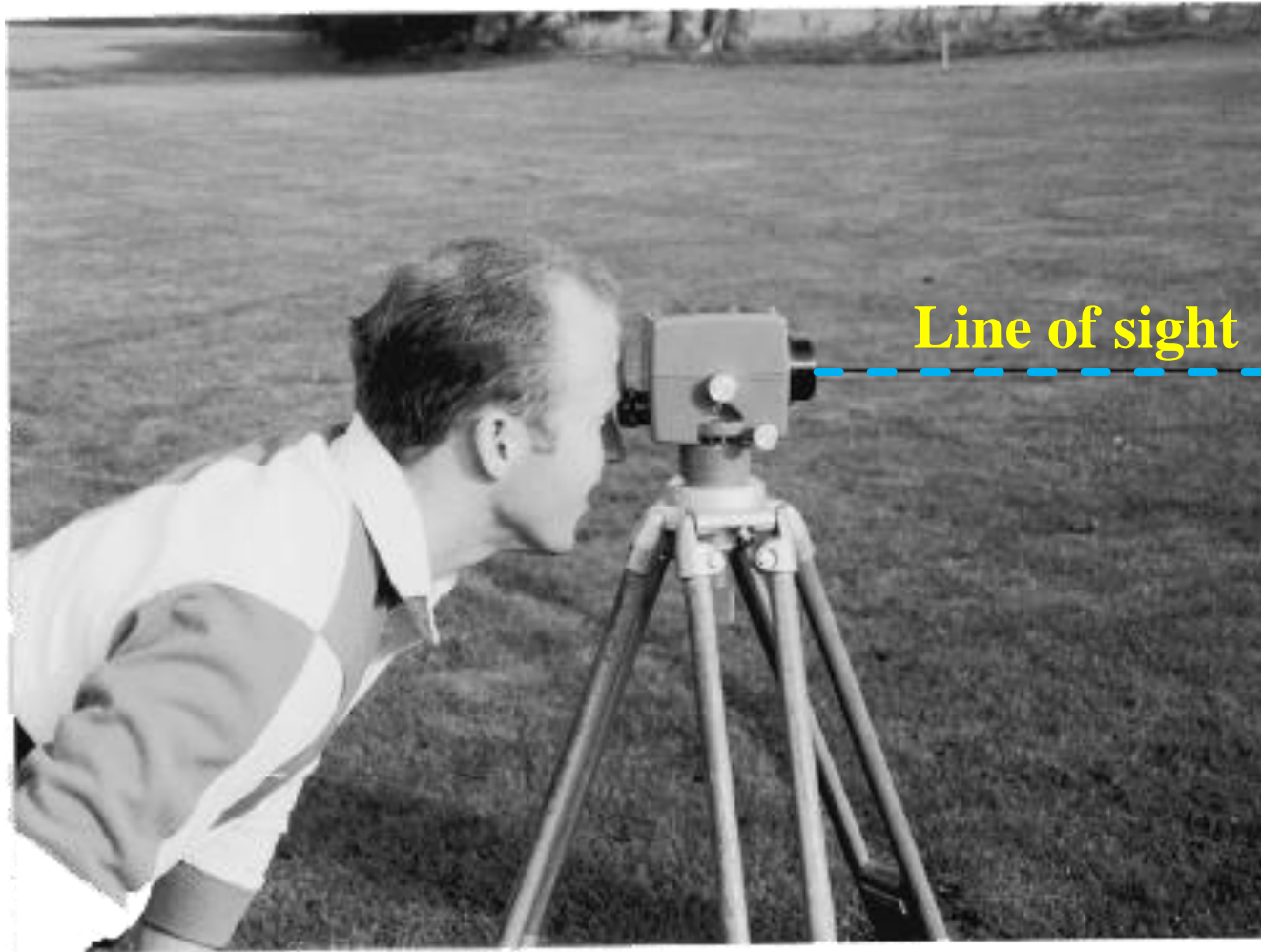
Do not use fences or walls



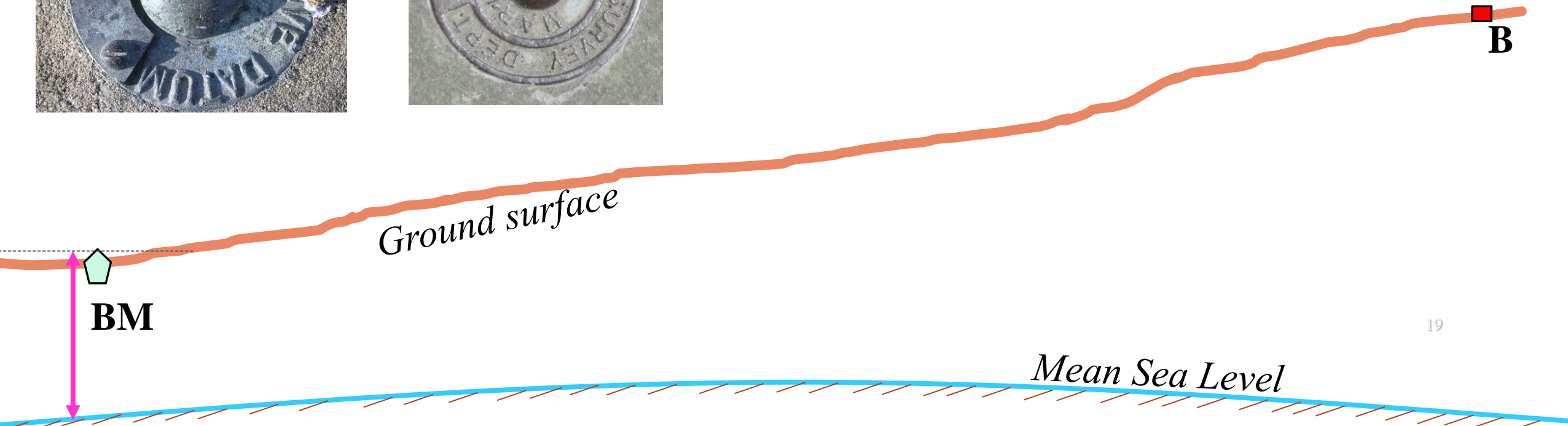
How to read levelling staff

The zero mark is at the bottom of the metal plate, read the [m], [dm] & [cm], but estimate the [mm]

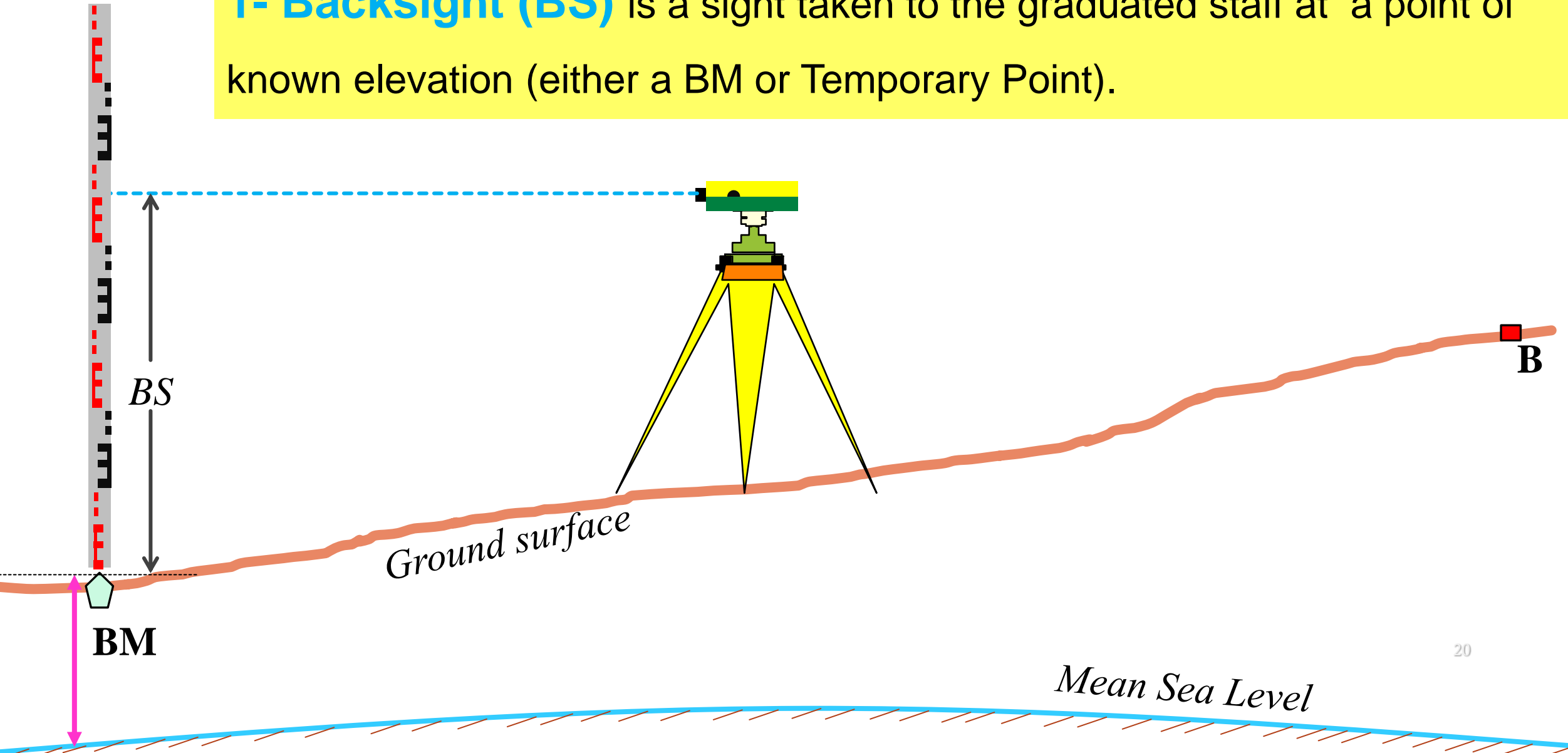




Benchmark (BM) is a permanent point of known elevation. BMs are established by using precise leveling techniques and instrumentation.



1- Backsight (BS) is a sight taken to the graduated staff at a point of known elevation (either a BM or Temporary Point).

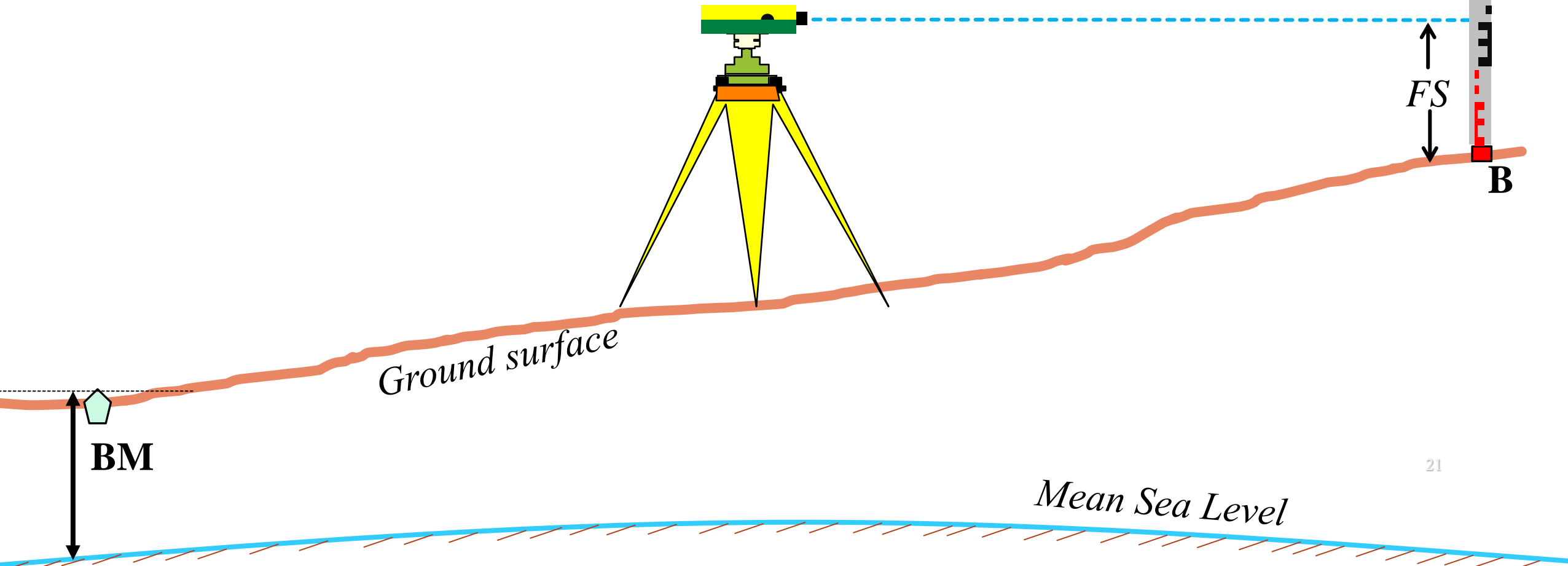


Differential leveling

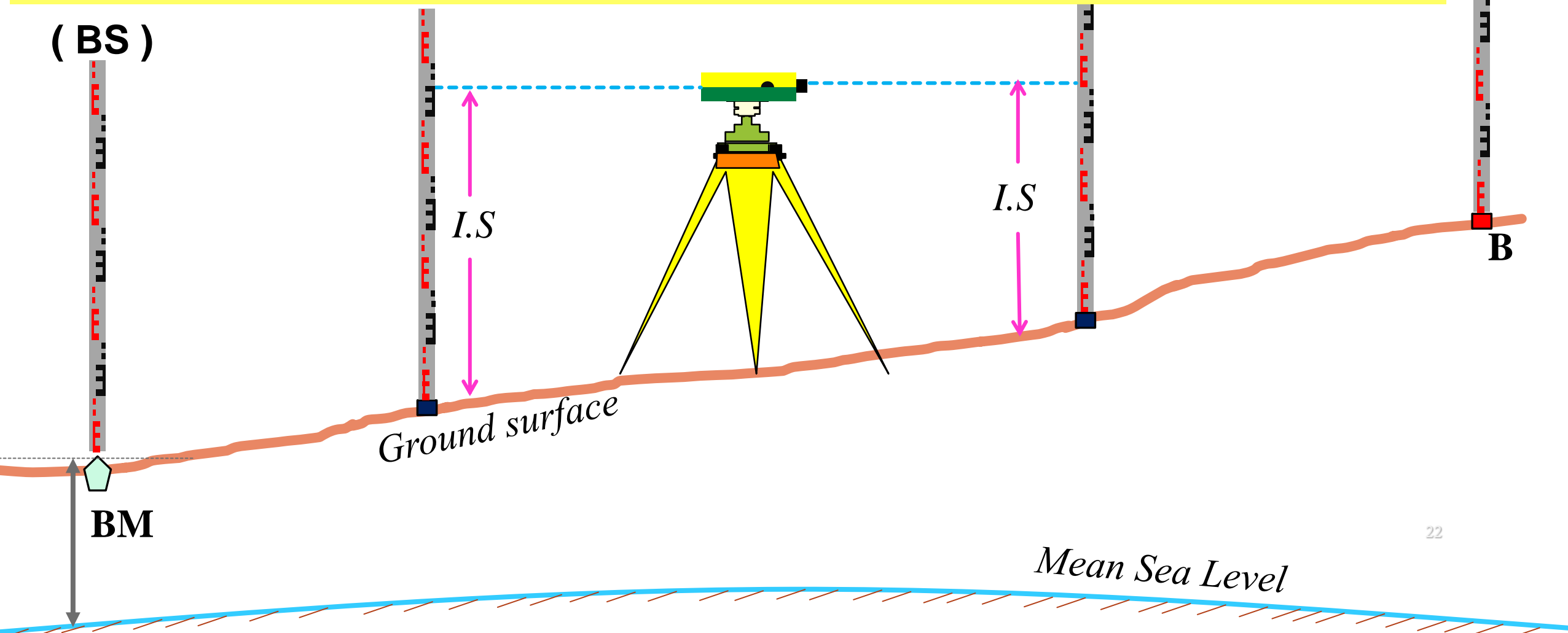


2- Foresight (FS) is a sight taken on any point to determine its elevation.

It is particularly the **last** sight taken before the level instrument is **moved to other location**.



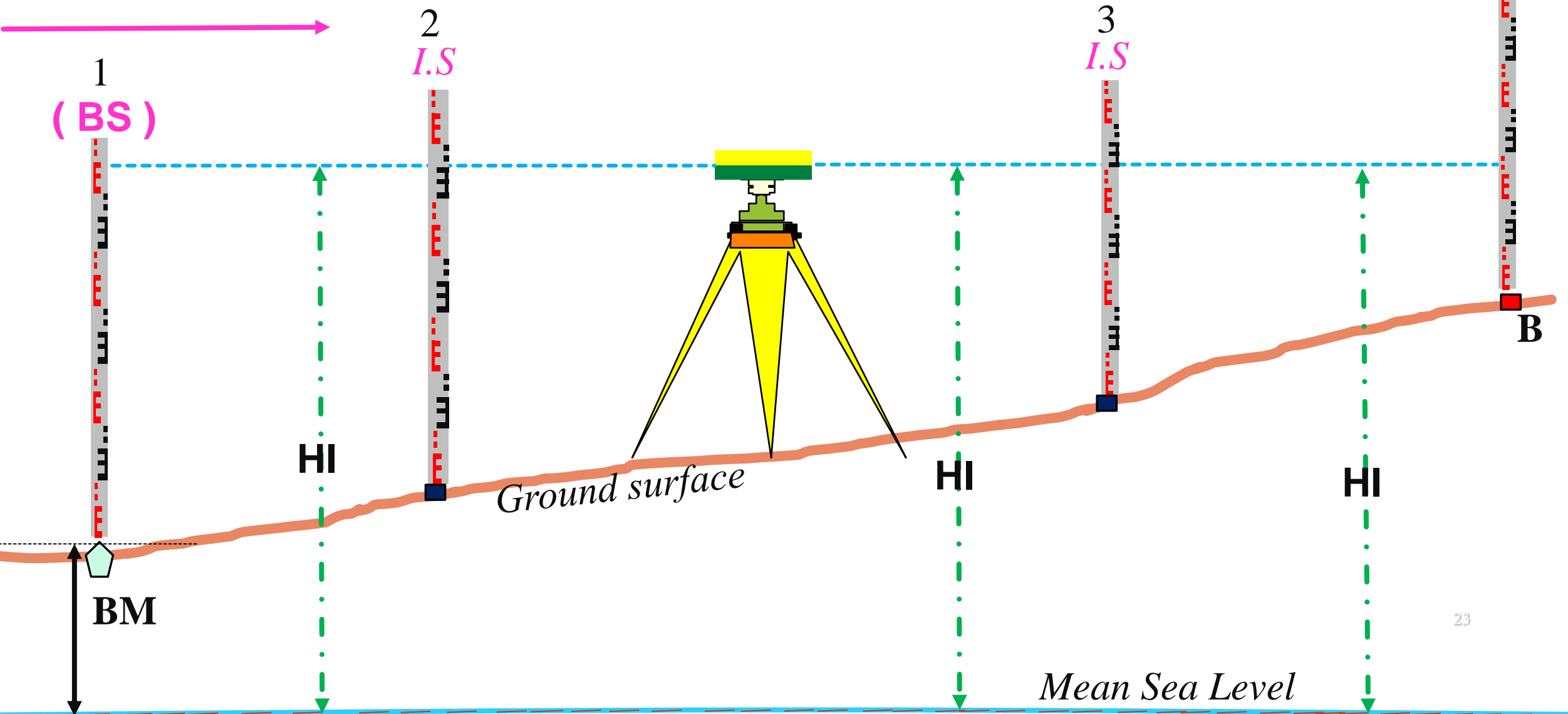
3- Intermediate sight (I.S) is a sight taken on any point to determine its elevation . It can be an sight taken between the **Backsight (BS)** and **Foresight (FS)**.



Differential leveling

4- Height of Instrument (**HI**) is the elevation of the line of sight of the telescope.

(**FS**)⁴



There are two methods for obtaining the elevations at different points:

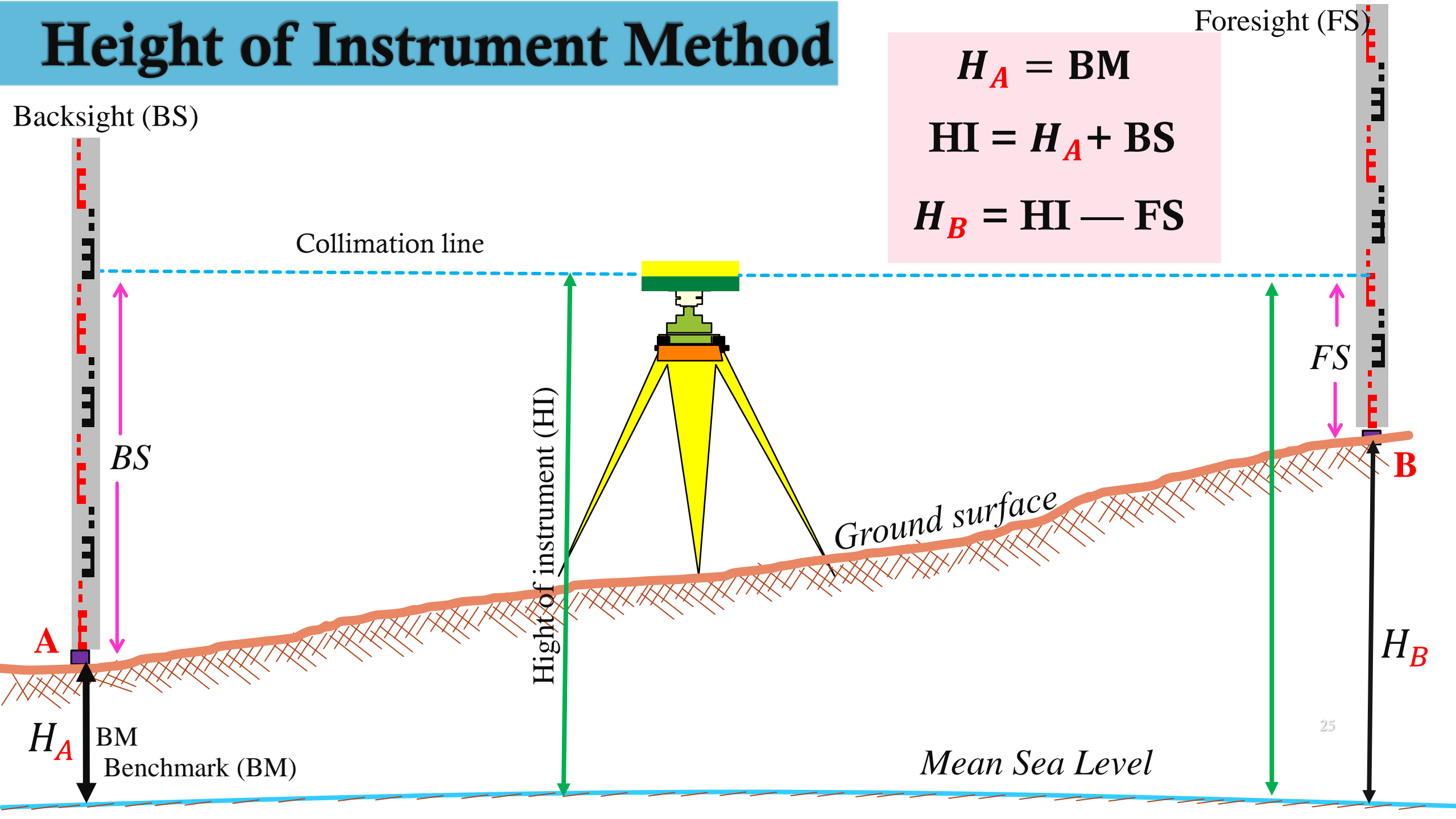
1- Height of instrument (or plane of collimation) method

This method consist of finding H.I. for every setup of instrument, and then obtaining the R.L. of point of reference with respect to H.I

2- Rise and fall method

This method consist of determining the difference of level between consecutive points by comparing each point with immediate preceding point.

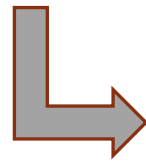
Height of Instrument Method



(1) Height of Instrument method (Height of collimation):

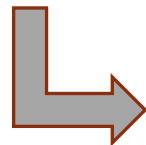
Differential leveling theory and applications can thus be expressed by two equations, which are repeated over and over

$$\text{Height of instrument} = \text{known elevation} + \text{Backsight}$$



$$\text{HI} = \text{Elev}_A + \text{BS}$$

$$\text{New elevation} = \text{height of instrument} - \text{foresight}$$



$$\text{Elev}_B = \text{HI} - \text{FS}$$

Arithmetic Check

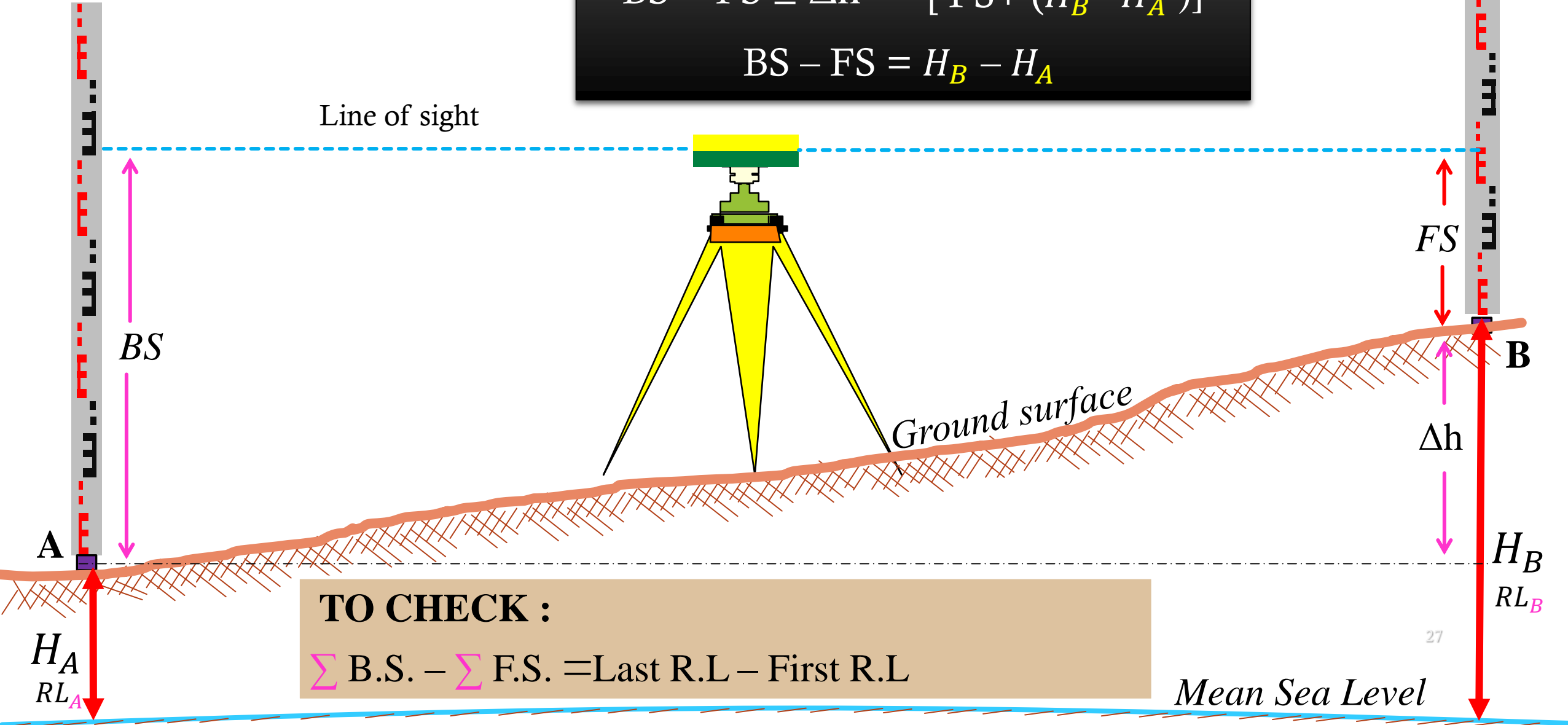
Backsight (BS)

Foresight (FS)

$$\Delta h = H_B - H_A = (RL_B - RL_A)$$

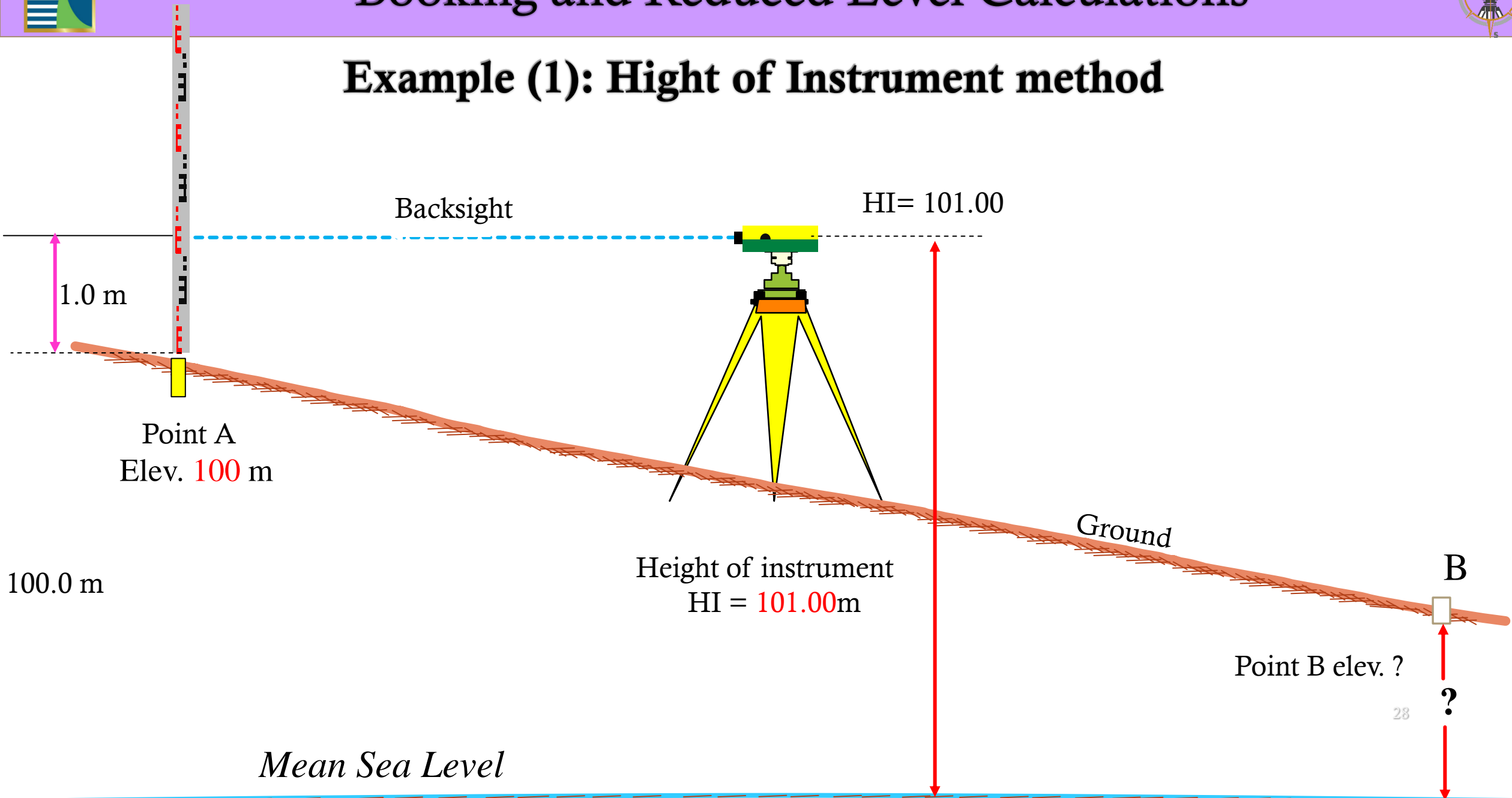
$$BS = FS \pm \Delta h = [FS + (H_B - H_A)]$$

$$BS - FS = H_B - H_A$$



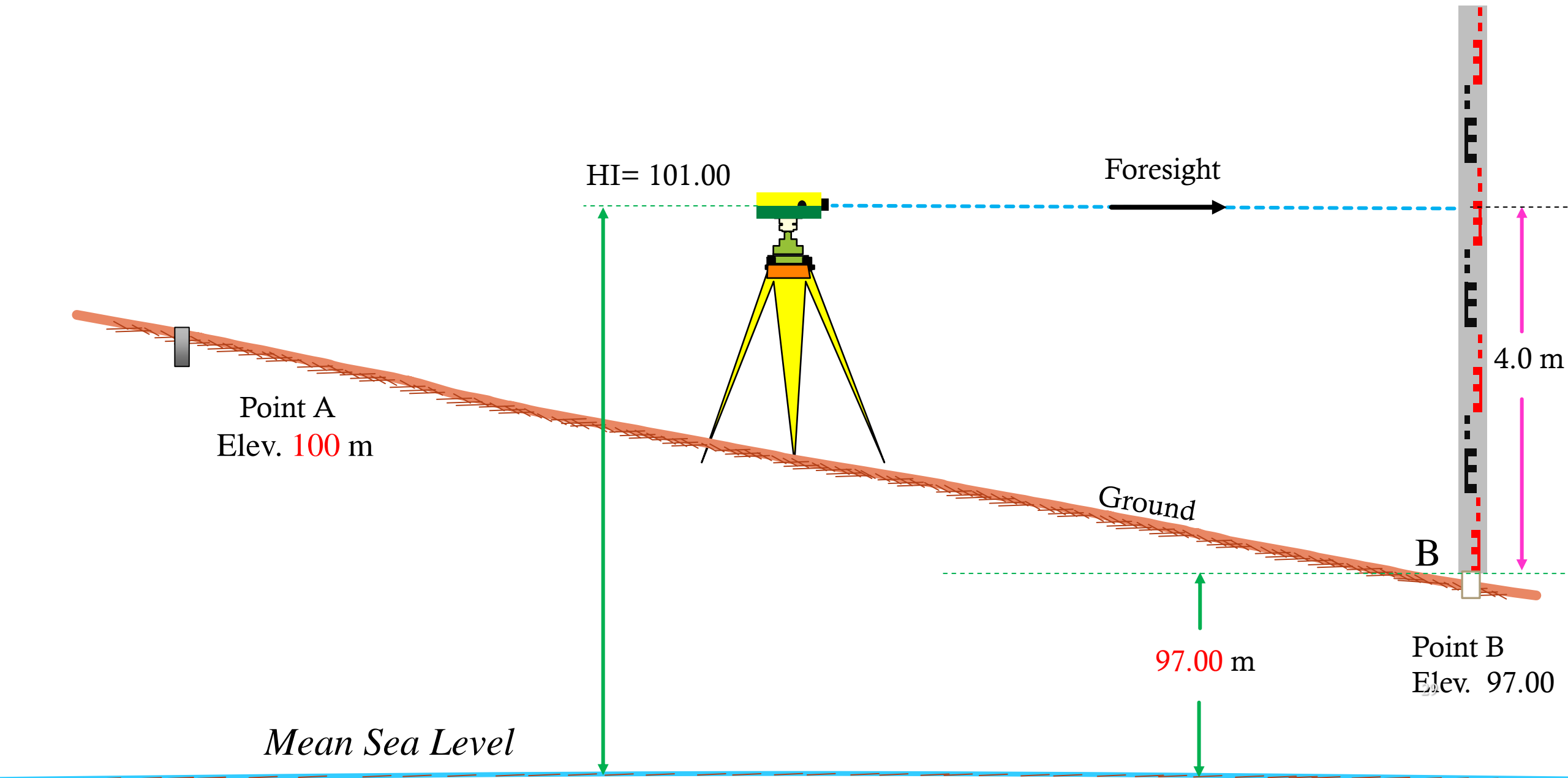
Booking and Reduced Level Calculations

Example (1): Hight of Instrument method





Example (1)



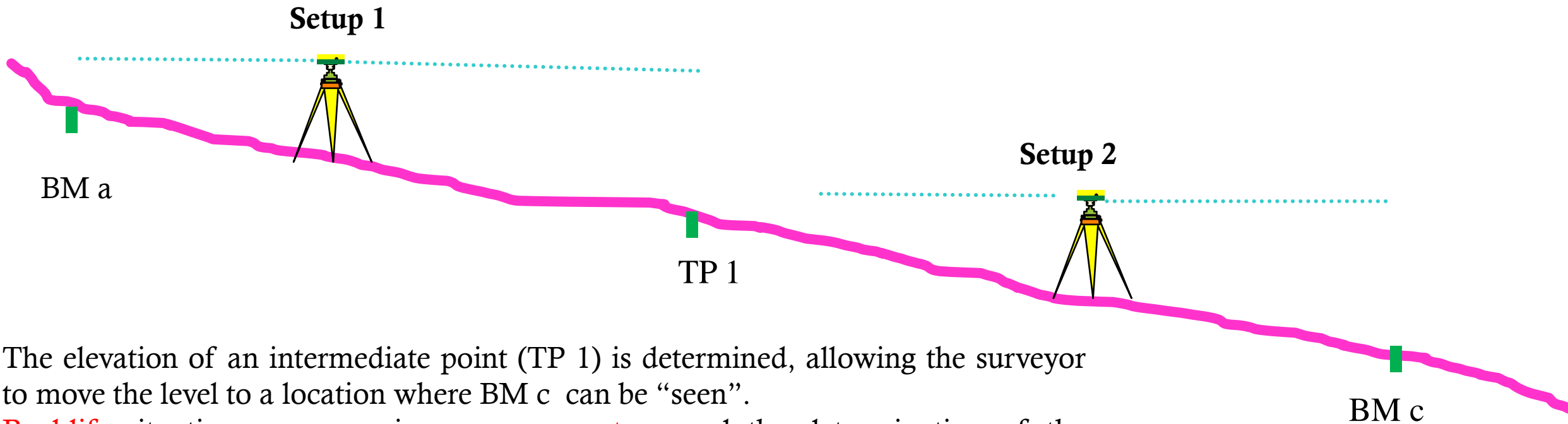


Turning point (TP)



A **turning point (TP)** is a point temporarily used to transfer an elevation

The situation depicted in the figure below shows the technique used when the point whose elevation is to be determined (BM c) is too far from the point of known elevation (BM a) for a one-setup solution.

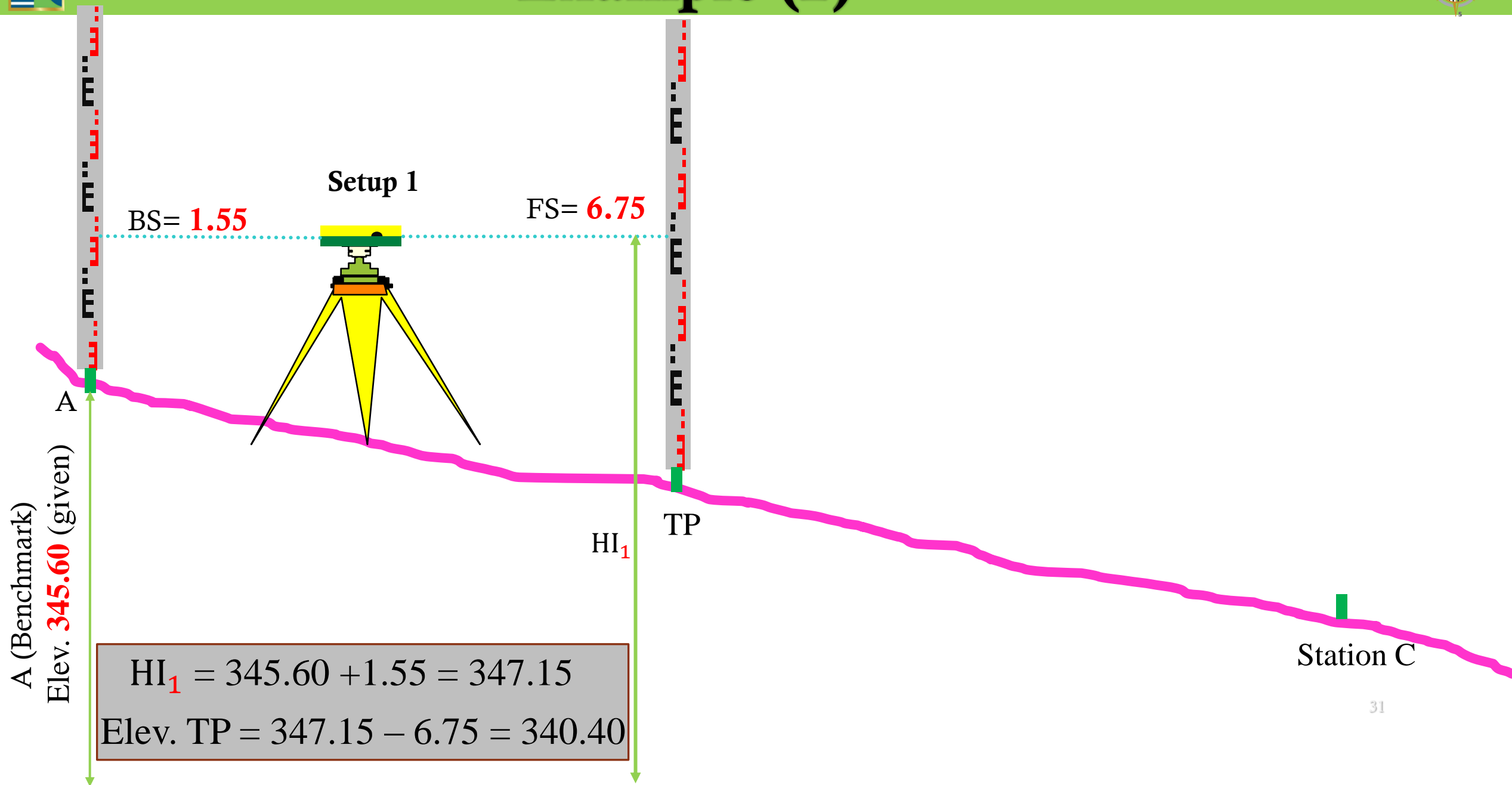


The elevation of an intermediate point (TP 1) is determined, allowing the surveyor to move the level to a location where BM c can be “seen”.

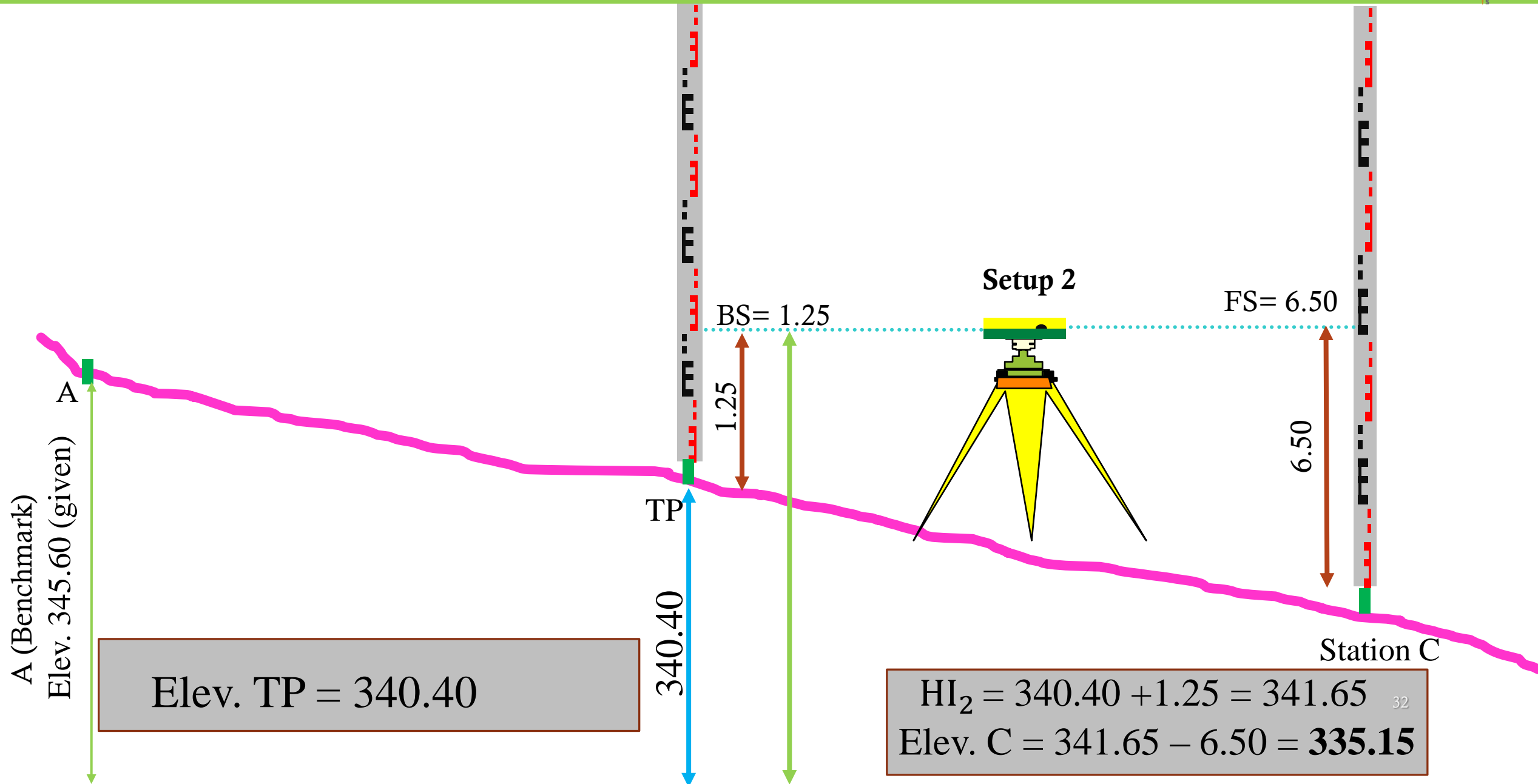
Real-life situations may require **numerous setups** and the determination of the elevation of many **turning points** before getting close enough to determine the elevation of the **desired point**



Example (2)

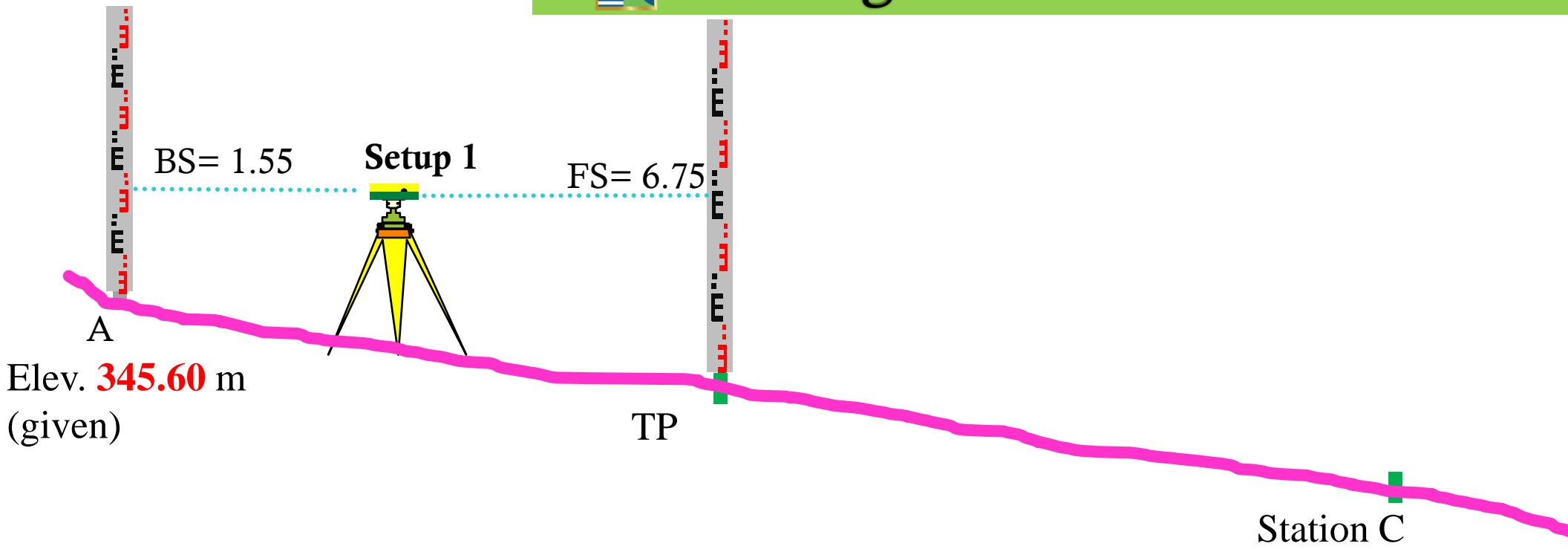


Example (2)





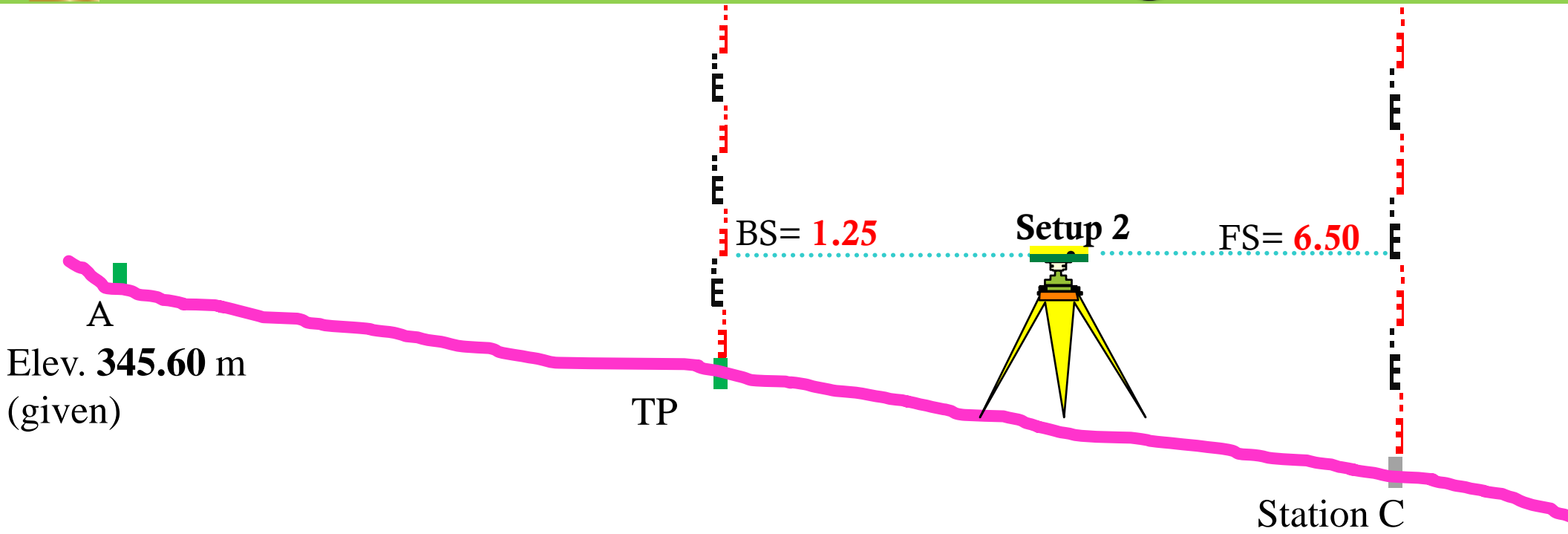
Booking and Reduced Level Calculations



Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55				345.60	
TP			6.75			
C						



Level booking



Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55				345.60	BM= H_A
TP	1.25		6.75			
C			6.5			

Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55			347.15 $(345.60 + 1.55)$	345.60	BM= H_A
TP	1.25		6.75			
C			6.5			

Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55			347.15 (345.60 + 1.55)	345.60	BM= H_A
TP	1.25		6.75		340.40 (374.15 – 6.75)	
C			6.5			

Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55			347.15 (345.60 + 1.55)	345.60	BM= H_A
TP	1.25		6.75	341.65 (340.40 + 1.25)	340.40	
C			6.5			

Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55			347.15 (345.60 + 1.55)	345.60	BM= H_A
TP	1.25		6.75	341.65	340.40	
C			6.5		335.15 (341.65 - 6.50)	

Arithmetic Check:

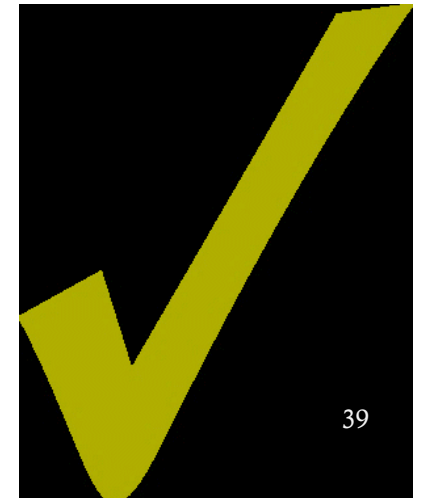
$$\sum \text{B.S.} - \sum \text{F.S.} = \sum \text{Last R.L.} - \sum \text{First R.L.}$$

Station	B.S	I.S	F.S	HI	R.L	Remarks
A	1.55			347.15	345.60	
TP	1.25		6.75	341.65	340.40	
C			6.5		335.15	

$$\sum = \underline{\underline{2.8}} \quad \underline{\underline{13.25}}$$

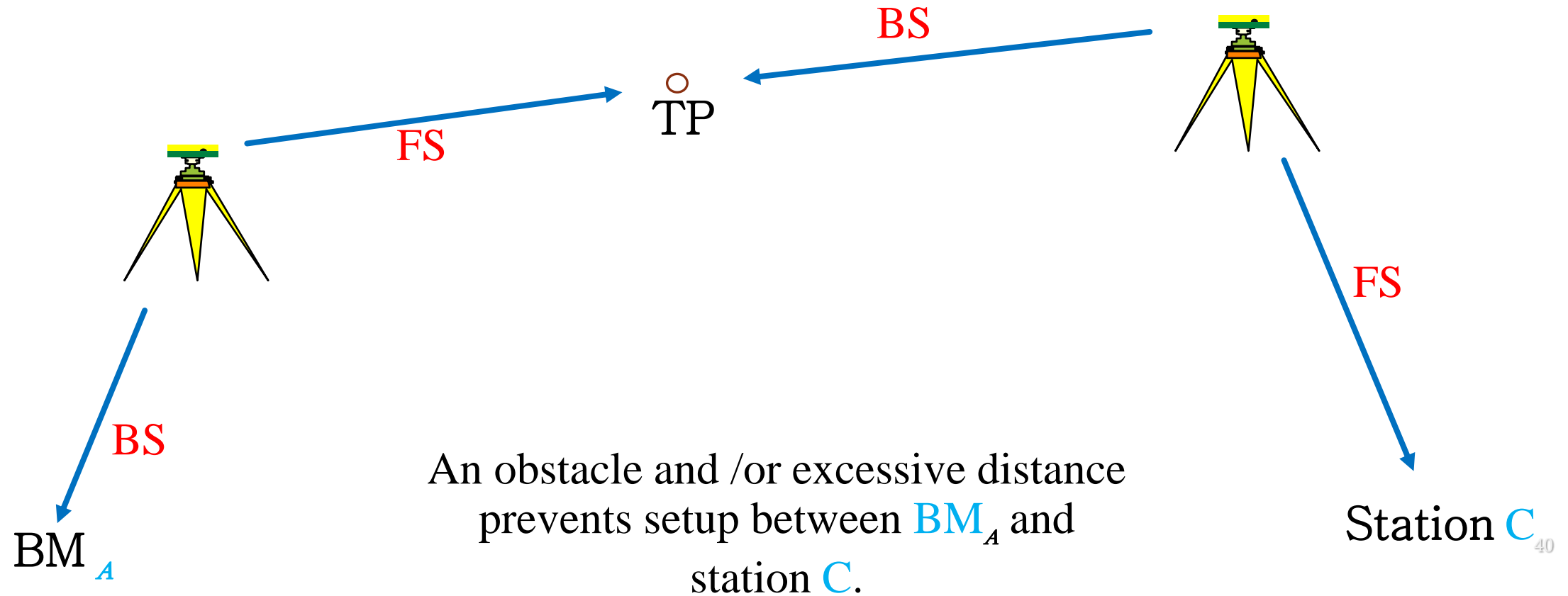
$$\sum \text{F.S.} - \sum \text{B.S.} = 13.25 - 2.8 = \underline{\underline{10.45}}$$

$$\text{First R.L.} - \text{Last R.L.} = 335.15 - 345.60 = \underline{\underline{10.45}}$$



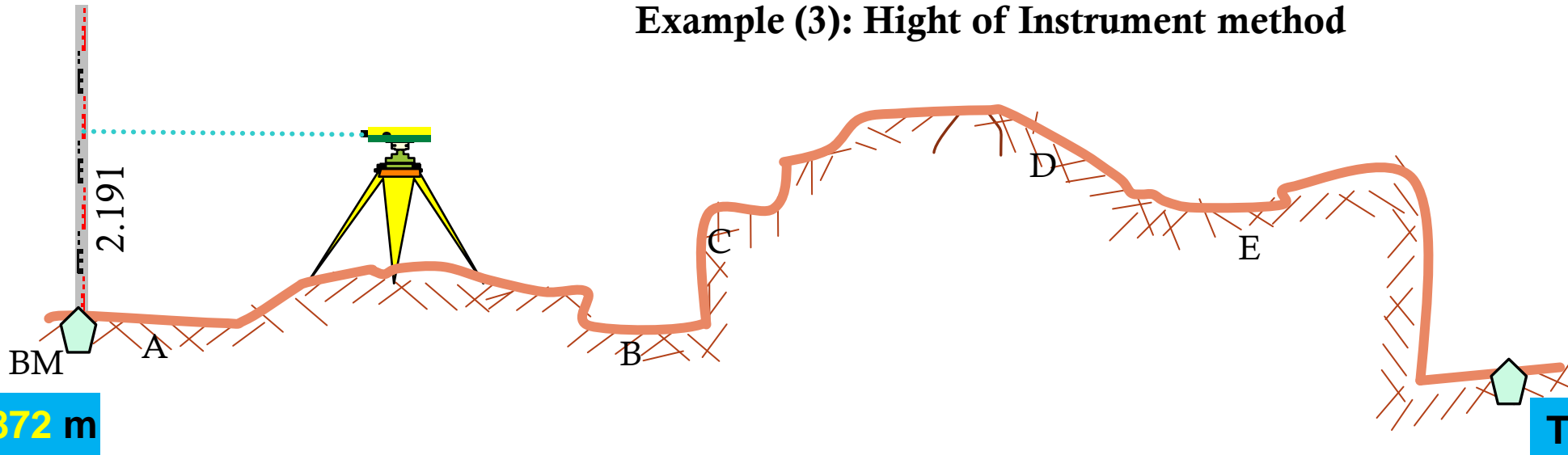
Often, the elevations of several points over a relatively long distance must be determined.

A process called *running levels* is used to determine the elevations of two or more widely separated points.



Example (3)

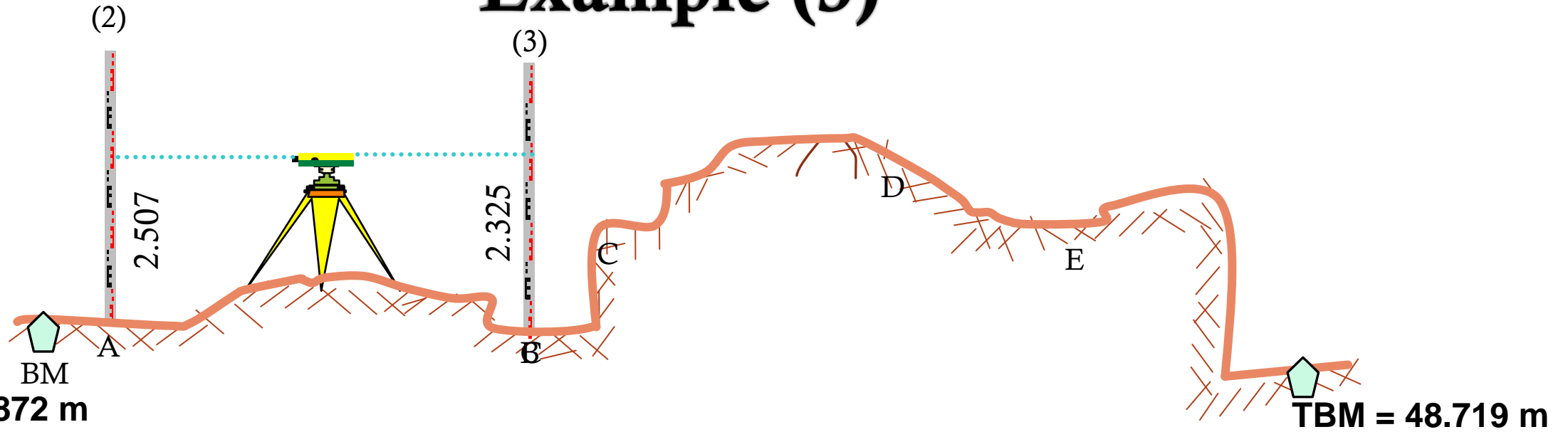
Example (3): Height of Instrument method



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A						
B						
C						
D						
E						41
TBM						48.719



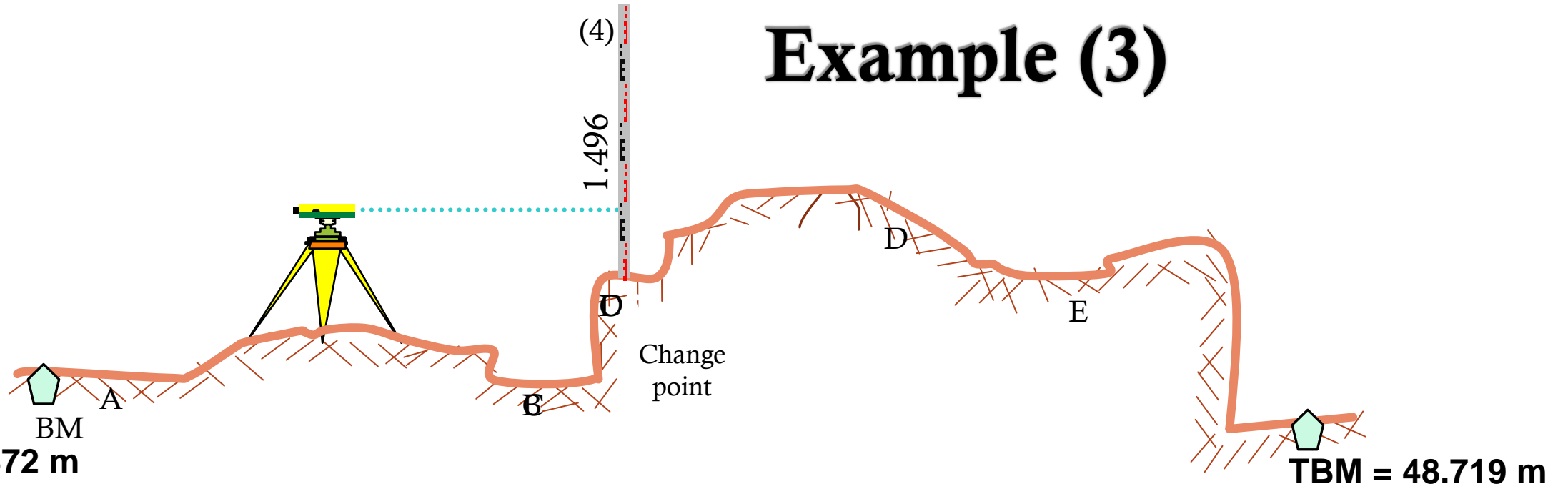
Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A		2.507				
B		2.325				
C						
D						
E						42
TBM						48.719



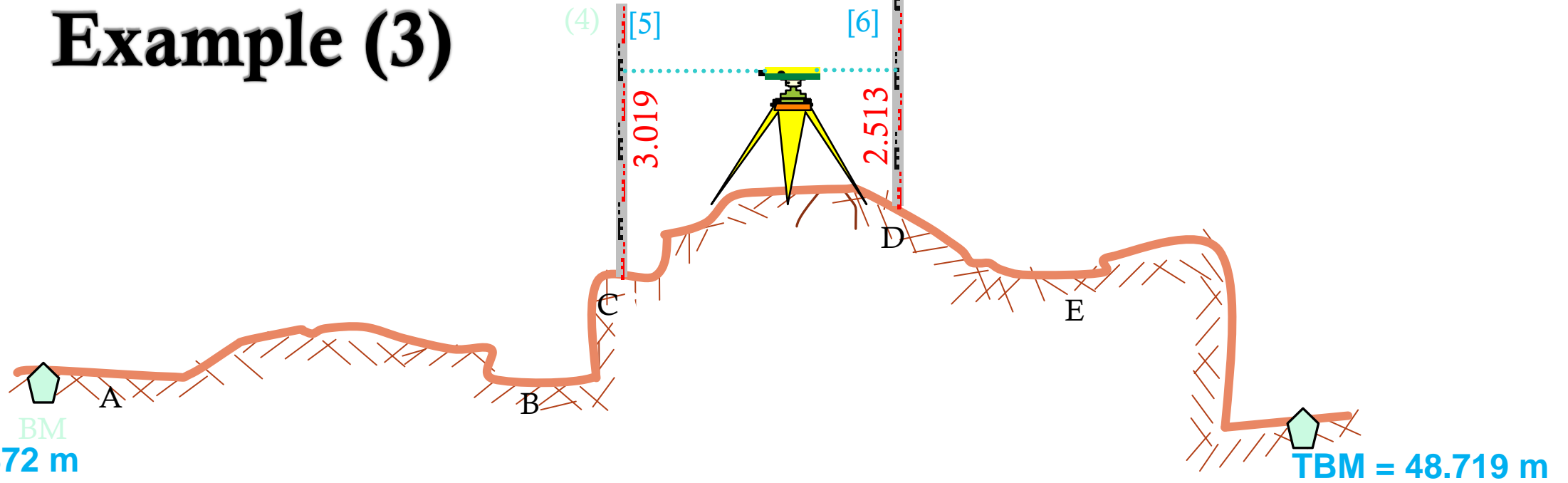
Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A		2.507				
B		2.325				
C			1.496			
D						
E						43
TBM						48.719



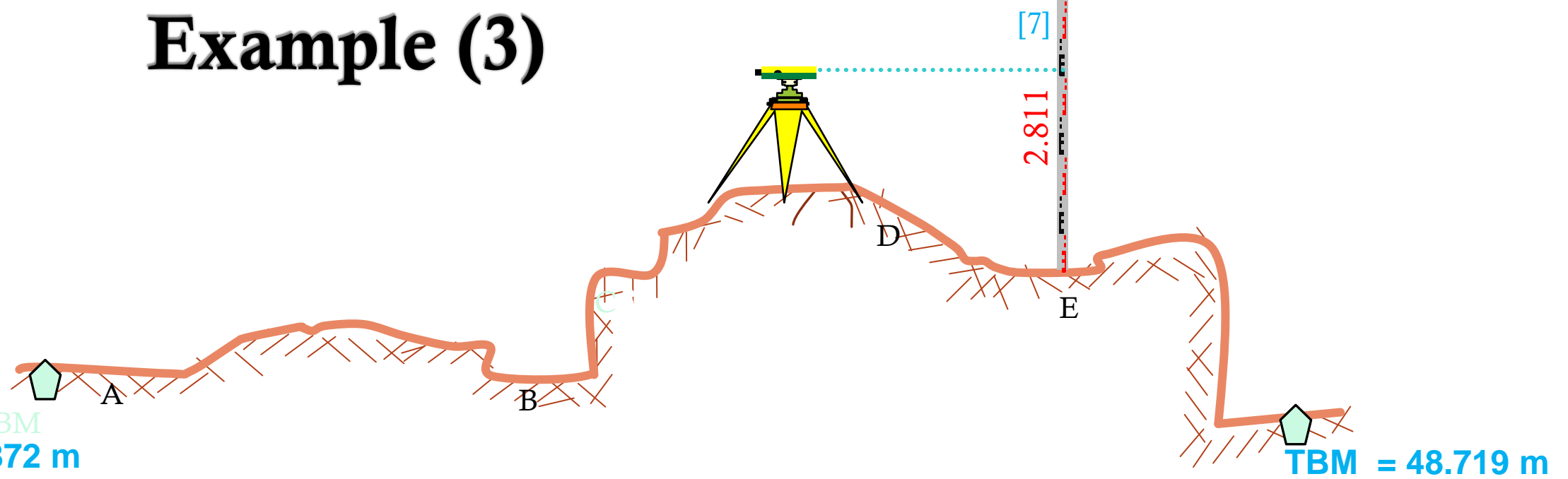
Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A		2.507				
B		2.325				
C	3.019		1.496			
D		2.513				
E						44
TBM						48.719



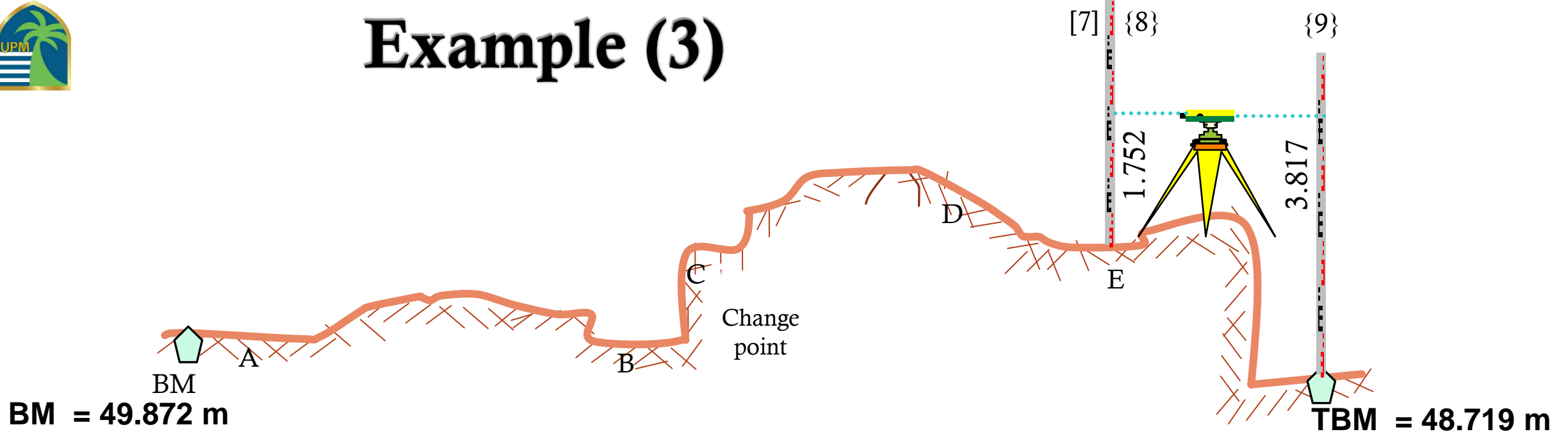
Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A		2.507				
B		2.325				
C	3.019		1.496			
D		2.513				
E			2.811			45
TBM						48.719



Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191					49.872 m
A		2.507				
B		2.325				
C	3.019		1.496			
D		2.513				
E	1.752		2.811			46
TBM			3.817			48.719

Example (3)

Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507				
B		2.325				
C	3.019		1.496			
D		2.513				
E	1.752		2.811			
TBM			3.817			TBM = 48.719 m

Example (3)

Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496		50.567	
D		2.513				
E	1.752		2.811			
TBM			3.817			TBM = 48.719 m

Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496	53.586	50.567	
D		2.513				
E	1.752		2.811			
TBM			3.817			TBM = 48.719 m

Example (3)

Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496	53.586	50.567	
D		2.513			51.073	
E	1.752		2.811		50.775	
TBM			3.817			TBM = 48.719 m

Example (3)

Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496	53.586	50.567	
D		2.513			51.073	
E	1.752		2.811	52.527	50. 775	
TBM			3.817		48.710	TBM = 48.719 m



Example (3)



Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496	53.586	50.567	
D		2.513			51.073	
E	1.752		2.811	52.527	50. 775	
TBM			3.817		48.710	TBM = 48.719 m

Arithmetic Check:

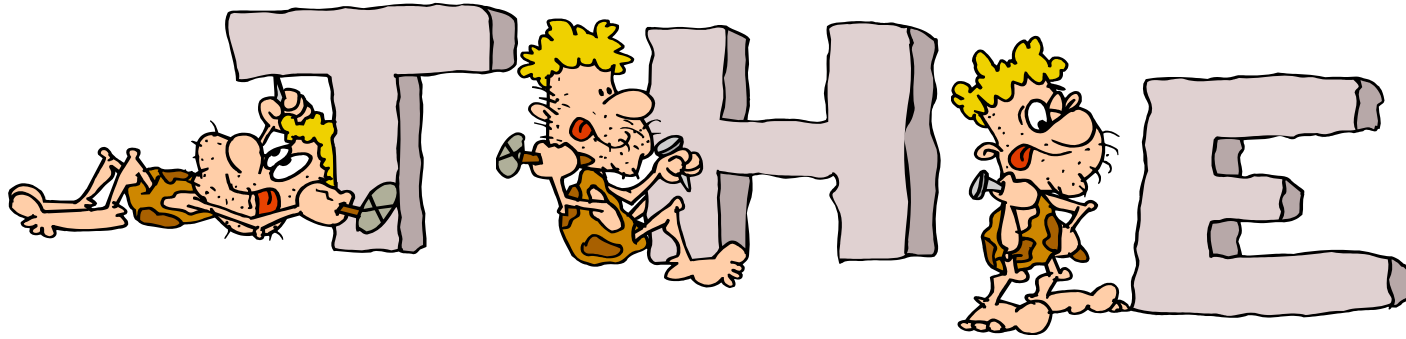
Station	B.S	I.S	F.S	HI	R.L	Remarks
BM	2.191			52.063	49.872 m	BM
A		2.507			49.556	
B		2.325			49.738	
C	3.019		1.496	53.586	50.567	
D		2.513			51.073	
E	1.752		2.811	52.527	50.775	
TBM			3.817		48.710	TBM = 48.719 m
	<u>6.962</u>		<u>8.124</u>			

$$\sum \text{F.S.} - \sum \text{B.S.} = 6.962 - 8.124 = \underline{\underline{1.162}}$$

$$\text{First R.L.} - \text{Last R.L.} = 48.710 - 49.872 = \underline{\underline{1.162}}$$

$$48.719 - 48.710 = 0.009$$





Special thanks to Eng. **Mohammed Barakat** (former UPM Lecturer) for making this animated Lecture